Establishment of Groundwater Source Protection Zones

Moyne Group Water Supply Scheme

(Private Scheme)

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Project description

Since the 1980's, the Geological Survey of Ireland (GSI) has undertaken a considerable amount of work developing Groundwater Protection Schemes throughout the country. Groundwater Source Protection Zones are the surface and subsurface areas surrounding a groundwater source, i.e. a well, wellfield or spring, in which water and contaminants may enter groundwater and move towards the source. Knowledge of where the water is coming from is critical when trying to interpret water quality data at the groundwater source. The Source Protection Zone also provides an area in which to focus further investigation and is an area where protective measures can be introduced to maintain or improve the quality of groundwater.

The project "Establishment of Groundwater Source Protection Zones", led by the Environmental Protection Agency (EPA), represents a continuation of the GSI's work. A CDM/TOBIN/OCM project team has been retained by the EPA to establish Groundwater Source Protection Zones at monitoring points in the EPA's National Groundwater Quality Network.

A suite of maps and digital GIS layers accompany this report and the reports and maps are hosted on the EPA and GSI websites (www.epa.ie; www.gsi.ie).

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1 Introduction

Groundwater Source Protection Zones (SPZ) have been delineated for the Moyne Group Water Supply (Private Scheme) according to the principles and methodologies set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999) and in the GSI/EPA/IGI Training course on Groundwater SPZ Delineation.

The Moyne Scheme is provided by two boreholes BH-1 (IE_SW_G_131_22_004) and BH-2 (no code) which are in the townland of Kilmakill and are approximately 2 m apart at the rear of a pump house.

The objectives of the study were:

- To outline the principal hydrogeological characteristics of the Kilmakill area where the supply wells are located.
- To delineate source protection zones for the wells.
- To assist the Environmental Protection Agency (EPA) and South Tipperary County Council in protecting the water supply from contamination.

The protection zones are intended to provide a guide in the planning and regulation of development and human activities to ensure groundwater quality is protected. More details on protection zones are presented in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

2 Methodology

The methodology applied to delineate the SPZ consisted of data collection, desk studies, site visits and field mapping and subsequent data analysis and interpretation.

An initial interview with the caretaker, and site and local area inspection, was undertaken on 28/06/2010. A further interview with the caretaker took place on site on 14/07/2010. Field mapping of the study area was also undertaken on this date. A pumping test was not carried out, as a test had been conducted in 1996.

While specific fieldwork was carried out in the development of this report, the maps produced are based largely on the readily available information and mapping techniques using inferences and judgements from experience at other sites. As such, the maps may not be definitively accurate across the whole area covered, and should not be used as the sole basis for site-specific decisions, which will usually require the collection of additional site-specific data.

3 Location, Site Description and Well Head Protection

The two wells are in a compound approximately 8.5 km north east of Thurles, as shown in Figure 1. The access to the site is via a third class road to the south of the road linking the villages of Manselstown and Kilmakill. The compound is protected by a palisade fence with access by a padlocked gate. The ground surface in the compound comprises granular fill. The two wells are situated 2 m apart at the rear of the pump house. The reservoir is situated 20 m to the west of the wells (Photo 1).

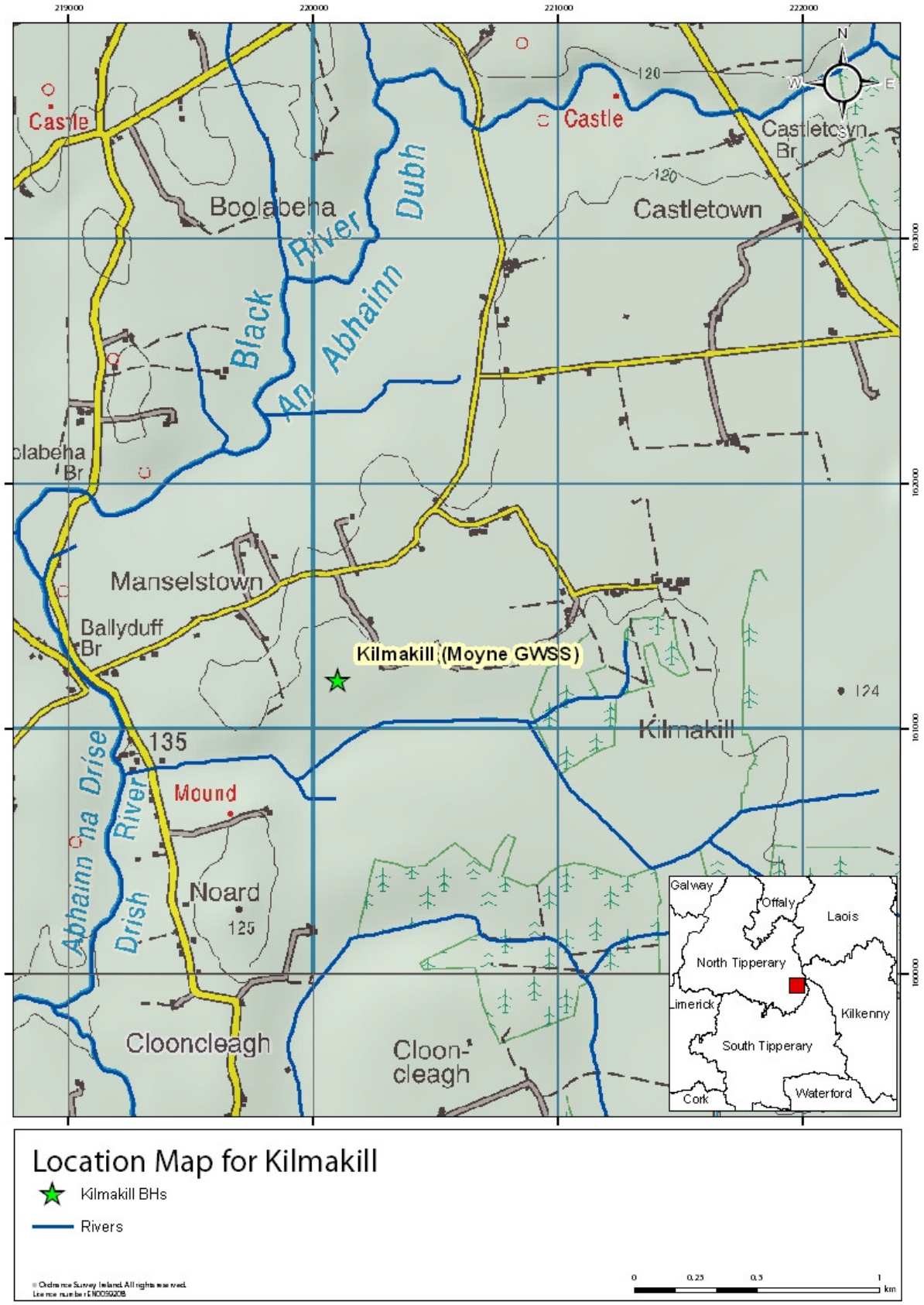

Figure 1: Location Map

Photo1: Site Layout

The boreholes, which were installed by Aquadril Services, are sealed to prevent surface water and/or shallow subsurface inflow. The boreholes' well head protection is shown in Photos 2, 3 and 4. The boreholes are on slightly raised concrete plinths on a rough concrete pad and both are fitted with a steel cover, with the well pipework plumbed into the pump house building. The steel top plate on each well has a port (c.60 mm threaded plug) to allow access for a water level meter and sampling equipment.

Water from the wells is pumped to the adjacent treatment plant for automated chlorination and filtration to reduce high iron and manganese levels. There is no cryptosporidium filter.

Photo 2: both wells

Photo 3: BH-1 Well Head Construction

Photo 4: BH-2 Well Head Construction

4 Summary of Well Details

The well details are derived primarily from the Report "Well Test at Stapletons" prepared by Aquadril Services in 1996, which is included in Appendix 1 and summarised in Table 3.1.

An initial test well was installed in the middle of an open field to a depth of 340 ft with an observation well installed to 200 ft. Following successful testing, the test well was extended to a depth of 122 m and a second well was installed immediately adjacent to it. These wells are the current water supply wells. Neither the drillers, nor the caretaker were aware of the location of the initial observation well used in the pump test and this could not be located during the field visit in 2010. The production boreholes were drilled at a diameter of 250 mm to a depth of 122 m. On completion of airlifting, a 200 mm nominal diameter PVC casing string was installed to the full depth. The casing string comprised an end cap, followed by 40 m of factory slotted PVC screen (with a maximum slot size of 1 mm). The remainder of the casing was plain PVC pipe.

The annulus between the casing and the borehole wall was filled to a depth of 80 m below ground level using clean, round pea gravel, with a range of diameters of between 5 and 20 mm. A 2 m thick sand plug was installed above the gravel pack. A bentonite cement grout was placed above the sand layer to a depth of 5 m below ground surface.

A water tight concrete inspection chamber of sufficient size to provide a minimum clearance of 300 mm around the casing was constructed around the top of the borehole. The chambers were topped with water tight load bearing manhole covers.

Table 4-1: Well Details

	BH-1	BH-2
EU Reporting Code	IE_SE_G_131_22_004	No Code
Grid ref. (GPS)	220074 161353	220074 161352
Townland	Kilmakill	Kilmakill
Source type	Borehole	Borehole
Drilled	1996	1996
Owner	Minorco Lisheen Limited	
Elevation (Ground Level)	~110 m OD	~ 110 m OD
Depth (m)	122 m	122 m
Depth of casing	122 m	122 m
Diameter	200 mm	200 mm
Depth to rock	3.6 m	2.4 m
Static water level	3.18 mbgl in 1996	3.18 mbgl in 1996
Pumping water level	10.20 m bgl for 45 m^3/h (28/06/2010) 4.2 m bgl when BH-2 was pumping (04/07/1996)	5.20 m bgl when BH-1 was pumping (28/06/2010) 5.4 m bgl for 54.50 m^3/h (04/07/1996)
Consumption (Co. Co. records)	45 m^3/h or 816 m^3/d	45 m^3/h or 816 m^3/d
Pumping test summary: (i) abstraction rate m^3/d	Not Tested	54 m^3/h or 1296 m^3/d
(ii) specific capacity	Expected to be in same range as BH-2	Approx 584 m^3/d/m
(iii) transmissivity	Expected to be similar to BH-2	1200 m^2/d

The water is pumped in each borehole in alternative months at 45 m^3/h, operating 18 hours per day on average, to a 360 m^3 capacity reservoir located in the compound. The abstraction rate depends on the demand, which results in fluctuations in the pumping duration. The maximum abstraction rate from each well is 816 m^3/d. This pumping rate has been sustainable since the wells were commissioned in 1997.

A pumping test was undertaken in 1996, which ran from July 1st to 4th. Pumping was carried out initially in BH-2, with drawdown monitored in BH-1 and BH-2. The well BH-2 was pump tested at three pumping rates: 27 m^3/h for 90 minutes; 41 m^3/h for 90 minutes and 54.50 m^3/hour for 2 days and 21 hours. The recovery was measured for 1 hour in both wells. The data are included in Appendix 1.

5 Topography, Surface Hydrology, Land Use

The wells are at an elevation of approximately 110 m OD. The topography of the study area is very flat and the land slopes gently from the east toward the Black River, which is 950 m west of the boreholes.

Drainage density is generally low in the catchment with much of the land comprising free draining agricultural grass land. To the south of the compound, there is an area of cut away peat bog where artificial drainage has been undertaken. It is likely that the water level in the drains in the bog is close to groundwater level locally. An unnamed stream rises 1.2 km to the east and flows from east to west through the cut away bog approximately 250 m to the south of the compound. The stream is a tributary of the Black River, with the confluence approximately 1 km to the west and downstream of the site. (Figure 1).

The landuse in the catchment is dominated by agriculture (animal grazing), with a small area of harvested peat bog to the south. There are three residential dwellings within 250 m of the compound.

6 Hydrometeorology

Establishing groundwater source protection zones requires an understanding of general hydrometeorological patterns across the area of interest. This information was obtained from Met Eireann.

Annual rainfall: 1000 mm, based on the contoured data map of rainfall in Ireland (Met Éireann website, data averaged from 1961–1990) which shows that the source is located close to the 1000 mm average annual rainfall isohyet.

Annual evapotranspiration losses: 494 mm. Average potential evapotranspiration (P.E.) is estimated to be 520 mm/yr based on the contoured data map of potential evapotranspiration in Ireland (Met Éireann website, data averaged from 1971–2000) which shows that the source is located close to the 520 mm average annual evapotranspiration isohyet. Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits.

Annual Effective Rainfall: 506 mm. The annual average effective rainfall is calculated by subtracting the actual evapotranspiration from the rainfall. Potential recharge is therefore equivalent to this, or 506 mm/year.

7 Geology

7.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the site. It provides a framework for the assessment of groundwater flow and delineation of the source protection zones.

The desk study data used comprised the following:

- Report 'Well test at Stapletons, Kilmakill, Moyne, Thurles, Co. Tipperary – Test Report' (Patrick Briody and Sons – Aquadril Services, 1996)
- Boreholes logs of test wells and production wells from Patrick Briody and Sons- Aquadril Services, 1996
- Geology of Tipperary. Bedrock Geology 1 : 100,000 Map series, Sheet 18, Geological Survey of Ireland (J.B. Archer, A.G. Sleeman and D. C. Smith, 1996)
- Forest Inventory and planning system – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map, Teagasc (Meehan, 2002)

7.2 Bedrock geology

Sheet 18, the Geology of Tipperary published by the GSI indicates that the area is underlain by the Aghmacart Formation (Dark shaly micrite, peloidal limestone) from the Dinantian Upper Impure Limestone Rock Unit Group (Figure 2). A thickness of some 200 m is recorded from drill core near Durrow (40 km to the north east). The two onsite boreholes were drilled to a depth of 122 m. The geological descriptions in the borehole logs are of limited value, but as no changes in bedrock type are identified, it is assumed that the boreholes were drilled exclusively in the Aghmacart Formation (Appendix 2).

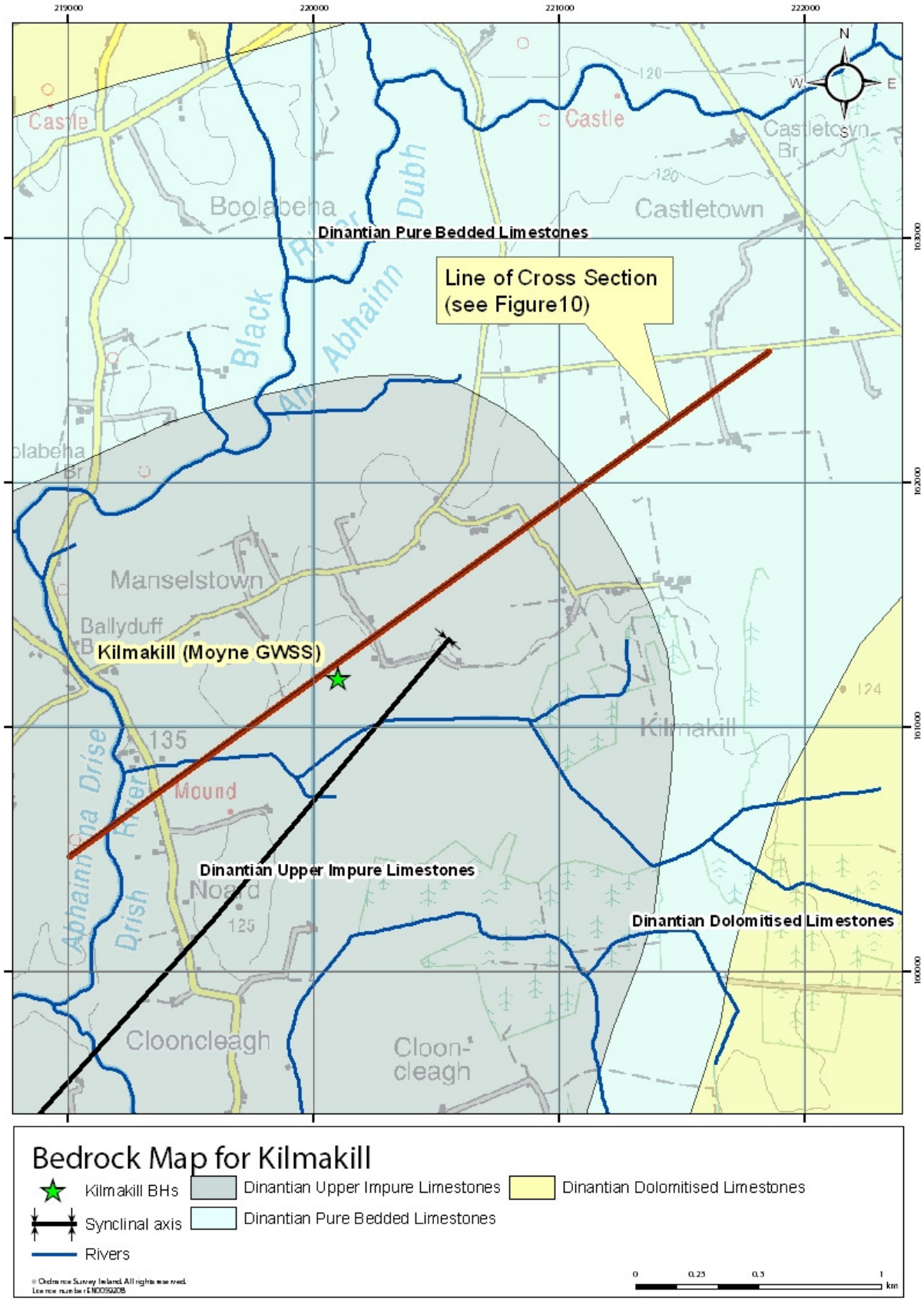

Figure 2: Bedrock/Rock Unit Map

The top of the bedrock is described as soft, brown, sand or weathered with brown clay infill. Clay infill is also recorded at depth (218 ft or 66.45 m) in BH-1 and at 105 ft or 32 m in BH-2. The unit beneath the Aghmacart formation is the Crosspatrick Formation which consists of pale well-bedded crinoidal limestones, often with copious seams and nodules of blue or black chert.

As indicated in the Bedrock Geology Map (Sheet 18) GSI, the limestone is often altered by the regional dolomitisation widespread in the underlying geological units. The dolomitisation enhances their mass permeability by creating additional void space. The soft brown top of rock described in borehole log BH-2 may be indicative of dolomite. The clay filled cavities recorded at depth in BH-1 and BH-2 may also be indicative of the presence of karstification.

The wells are located in the vicinity of a SW-NE syncline axis which runs between Two-Mile-Borris and Thurles. The bedding dips gently to the northwest in the vicinity of the wells. The geological map (Figure 2) does not indicate the presence of any significant faults in the formation in the catchment of the boreholes. However, it is likely fracturing and faulting that accompanied the folding of the limestone has likely given rise to zones of enhanced permeability locally.

There are two, large NNE to SSW trending faults mapped between two and three kilometres respectively, to the south and the north of the wells. A major NNW-SSE trending fault complex is located 5 km to the north.

7.3 Soil and subsoil geology

The soil and subsoil distributions are illustrated in Figures 3 and 4, respectively. The EPA and GSI Web Mapping classify the soil as Basic Mineral Deep Well Drained (BminDW). The maps show a small area of cut away bog to the south of the boreholes, which is consistent with field observations. The peat is very thin, c.0.3 m, based on observations in the field drains in the bog. The cut away bog is the northern margin of a more extensive peatland area to the south and east.

Bedrock outcrops were observed adjacent to the compound, and rock is close to the ground surface within c.200 m of the wells, and also approximately 1 km to the east within the topographic catchment of the wells. Over the rest of the catchment, the bedrock is overlain by a relatively thick succession (>3 m) of Carboniferous Limestone Till (TLs) subsoil derived from the underlying Dinantian Upper Impure Limestone bedrock. Field mapping indicates that beneath the peat to the south of the boreholes, the subsoils comprise sandy silt (Till).

In general, the subsoil is classified as sandy silt and the permeability is characterised as moderate based on BS5930 field assessment of subsoil samples and supported by field observations of well drained lands over most of the catchment. Along the southern margins of the catchment in the bog, permeability is considered to be low.

7.4 Depth to bedrock

The GSI vulnerability classification for the study area indicates that the depth to bedrock is no more than 3 m bgl, with rock near the surface in the vicinity of the wells and within the topographic catchment approximately 1 km to the east. Over the remainder of the catchment, the subsoil thickness is mapped as being between 3-5 m deep.

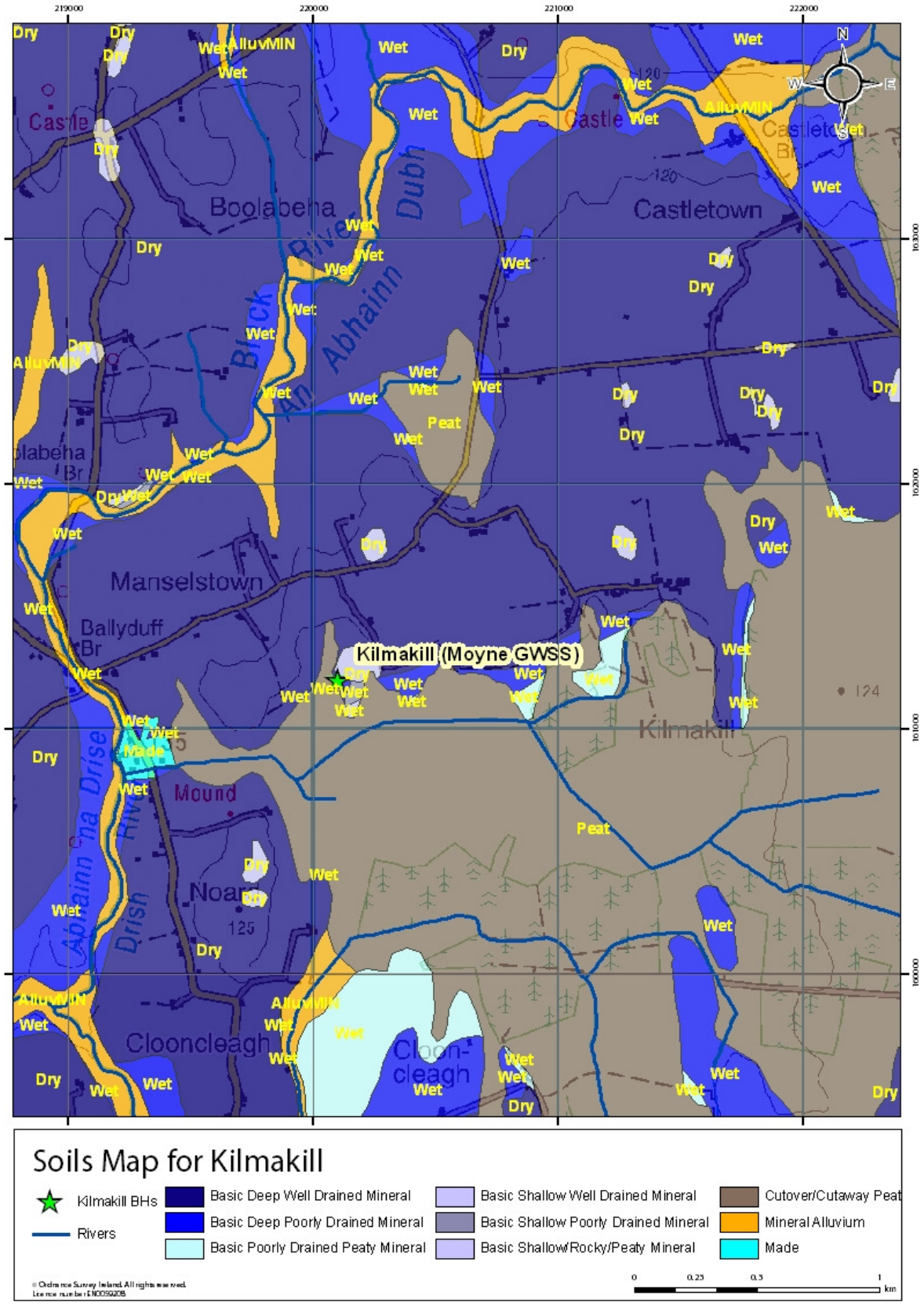

Figure 3:Soils Map

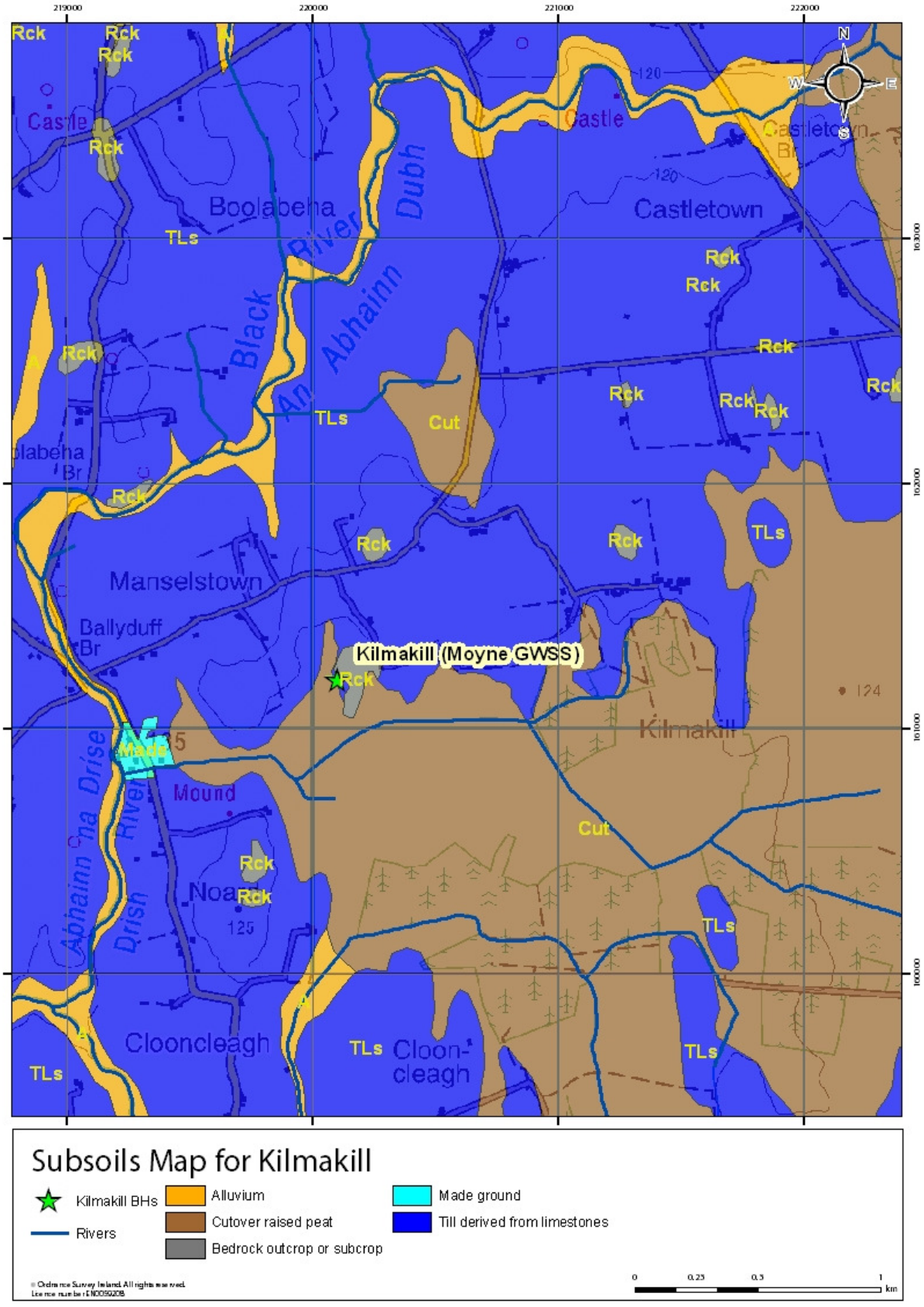

Figure 4: Subsoils Map

The borehole logs for BH-1 and BH-2 indicate a depth to bedrock of between 3.6 and 2.4 m bgl. During the field mapping, bedrock outcrop was observed adjacent to the compound, within c.200 m of the wells and 1.1 km to the east of the site. The field observations are consistent with the available mapping data.

8 Groundwater Vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. This means that in this area the vulnerability relates to the permeability and thickness of the subsoil. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999) and in the draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination (Fitzsimons et al, 2003).

Currently only Interim vulnerability mapping for the Tipperary North area has been carried out with rock close to the surface, extreme and 'high to low' zones provisionally defined. Over the main portion of the study area, a detailed vulnerability map was developed during the course of this project by Dr. Robert Meehan who was also part of the SPZ field mapping team. A full vulnerability map for the Tipperary North area is due for completion in 2011/2012.

The vulnerability map is shown in Figure 5. In terms of subsoil coverage within the catchment of the wells, the area can be divided into two zones:

- Within 200 m of the well and at the east margins of the catchment area, the subsoil is either very thin or absent. Here, the vulnerability is classed as Extreme (E) or Extreme with Rock near the surface (X).
- In the remainder of the catchment, the subsoil thickness ranges from between 3 and 10 m and the vulnerability is classed as High.

9 Hydrogeology

This section describes the current understanding of the hydrogeology in the vicinity of the wells. Hydrogeological and hydrochemical information was obtained from the following sources:

- GSI Website and Database
- County Council Staff
- EPA website and Groundwater Monitoring database
- Local Authority Drinking Water returns
- Report 'Well test at Stapletons, Kilemakill, Moyne, Thurles, Co. Tipperary – Test Report' (Patrick Briody and Sons- Aquadril Services, 1996)
- Source Protection Scheme Report for Two Mile Borris (GSI, 2002)

9.1 Groundwater body and status

The boreholes are located within the Templemore B Groundwater Body (IE_SE_G_131) which has been classified as being of Good Status. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the Water Framework Directive website: www.wfdireland.ie/maps.html.

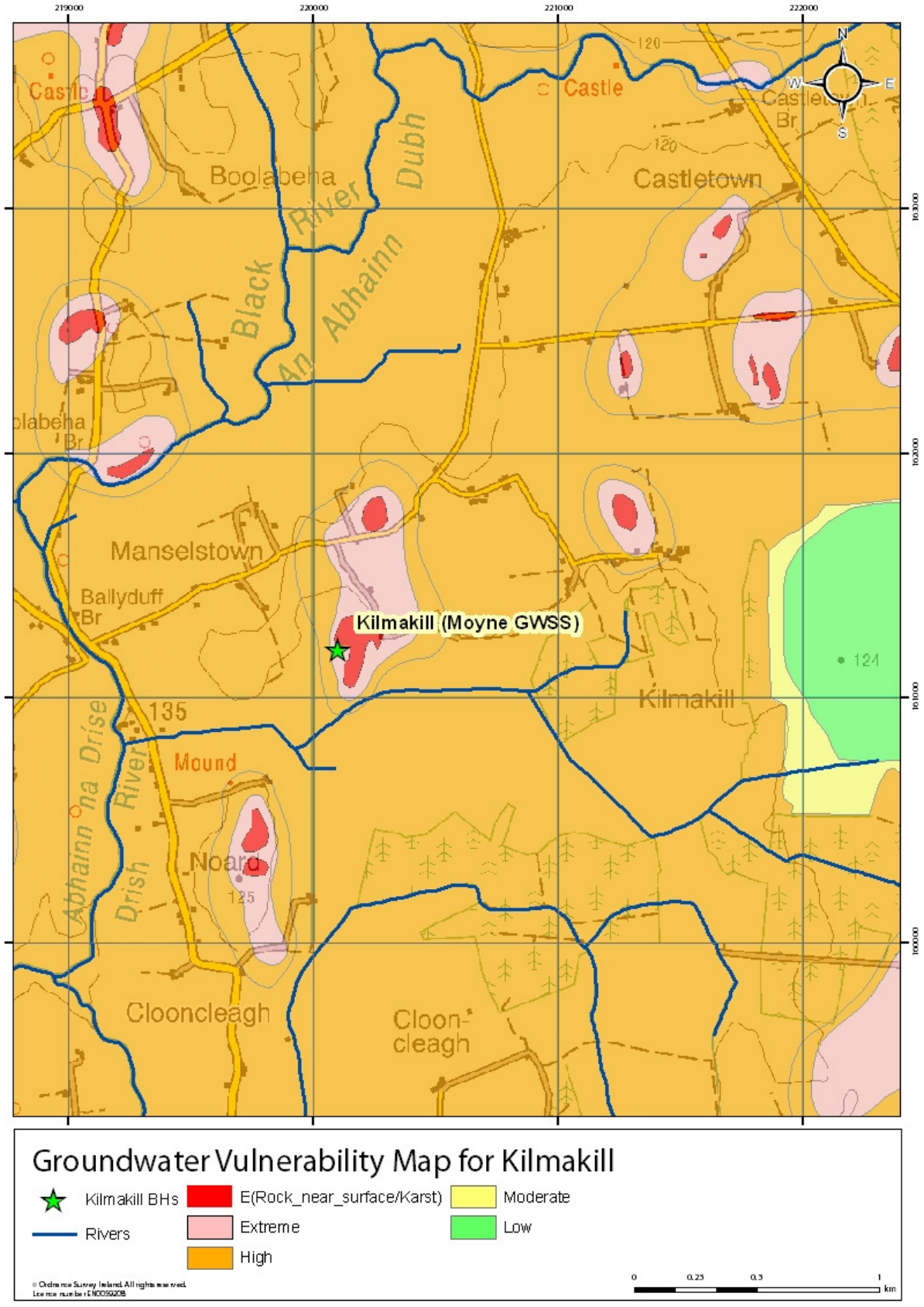

Figure 5: Vulnerability Map

9.2 Groundwater Levels, Flow Directions and Gradients

Groundwater level monitoring in the wells prior to the 1996 pumping test, found the level in BH-1 was 3.17 m bgl, while the level in BH-2 was 3.18 m bgl. On the 28th June 2010, while the well BH-1 was being pumped at 45 m^3/h, the water level in BH-1 was recorded as being 10.2 m bgl, while in BH-2 it was 5.20 m bgl.

Based on the topography and local surface water drainage pattern, groundwater infiltrates the bedrock through the permeable subsoils and flows to the south-west towards Black River. Given that the Aghmacart Formation is likely to have enhanced permeability as a result of dolomitisation and/or karstification, it is anticipated that the groundwater gradient is shallow and likely to reflect the local topography.

There are two wells identified in the GSI Wells database located within 1 km of the site. One is approximately 150 m north of the site, while the other is approximately 900 m to the east. Neither well could be accessed to monitor water levels during the field mapping programme. However, the water level in the field drains in the till (c.1.8 m bgl) approximately 200 m to the east is thought to be close to groundwater level.

In its 2002 report, the GSI refers to a hydraulic gradient for the Aghmacart formation in the Two-Mile Borris area, which is 3 km to the south of the site, of approximately 0.0025. Using a digital terrain and topographic contour comparison of the Kilmakill and Two Mile Borris area, the topographic gradient in the vicinity of the site is similar to Two Mile Borris The topographic gradient in the vicinity of the source is estimated to be around 0.002.

9.3 Hydrochemistry and Water Quality

The well has been included in the EPA operational chemical network since 1995. The raw water sample point is a tap located inside the pump house. The laboratory results have been compared to the EU Drinking Water Council Directive 98/83/EC Maximum Admissible Concentrations (MAC) and where applicable the European Communities Environmental Objectives (Groundwater) Regulations 2010 recently adopted in Ireland under (S.I. No. 9/2010) as part of the implementation of the Water Framework Directive 2000 in Ireland. The data are summarized graphically in Figures 6 to 8 and are summarised below.

Some initial water quality testing was also undertaken during pump testing after the wells were installed in 1996. These data are included in Appendix 1 and incorporated in the summary tables below.

- The water has a very hard calcium bicarbonate hydrochemical signature (average 410 mg/l $CaCO_3$). The average conductivity is 766 µS/cm and pH is around 7.1.
- There are 13 reported incidents of faecal coliforms in the total of 30 analyses (Figure 6). Ammonium values higher than the Threshold Level (0.175 mg/l) were recorded on two occasions. Combined elevated ammonium and faecal coliforms only occurred on one occasion (Nov. 2007).

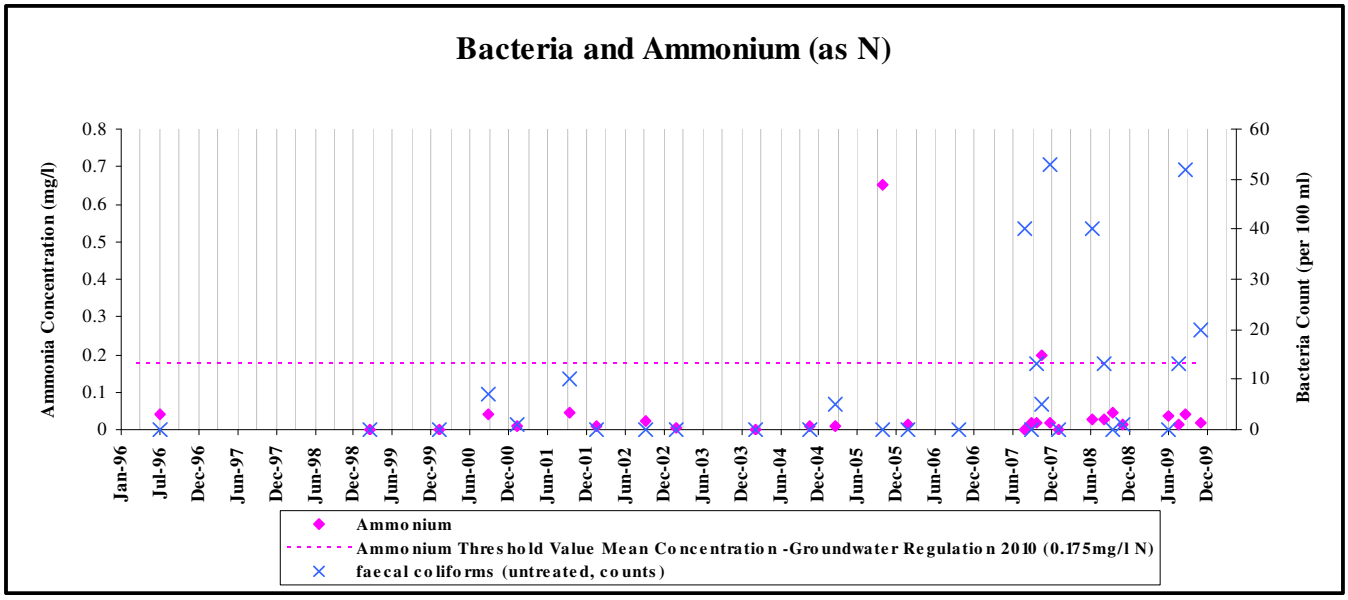

Figure 6 Key Indicators of Agricultural and Domestic Contamination: Bacteria and Ammonium

- The nitrate (as NO3) level ranges from 4.3 mg/l to 50.9 mg/l, with a mean of 24.7 mg/l (Figure 7). The EU Drinking Water Directive maximum admissible concentration (MAC) (50 mg/l) has been exceeded only one time in July 1996 (sample was taken 1 day after the start of the pumping test). The threshold value of 37.5 mg/l has been exceeded on four occasions (July 1996, Sept. 2000, Nov. 2004 and Feb. 2006). Since 2008, the level has decreased significantly.
- Chloride can be a constituent of organic wastes and mean values higher than 25 mg/l may indicate contamination. Levels above 30 mg/l may be indicative of significant contamination (Daly 1996), with levels higher than the MAC value 250 mg/l usually indicating significant contamination. Chloride concentrations range from 9 mg/l to 31 mg/l with a mean of 20.1 mg/l (Figure 7). The threshold value has been exceeded on ten occasions. However, since 2008 and coincident with the decrease in nitrate levels, the chloride has been significantly reduced and is now below the regulation limit.

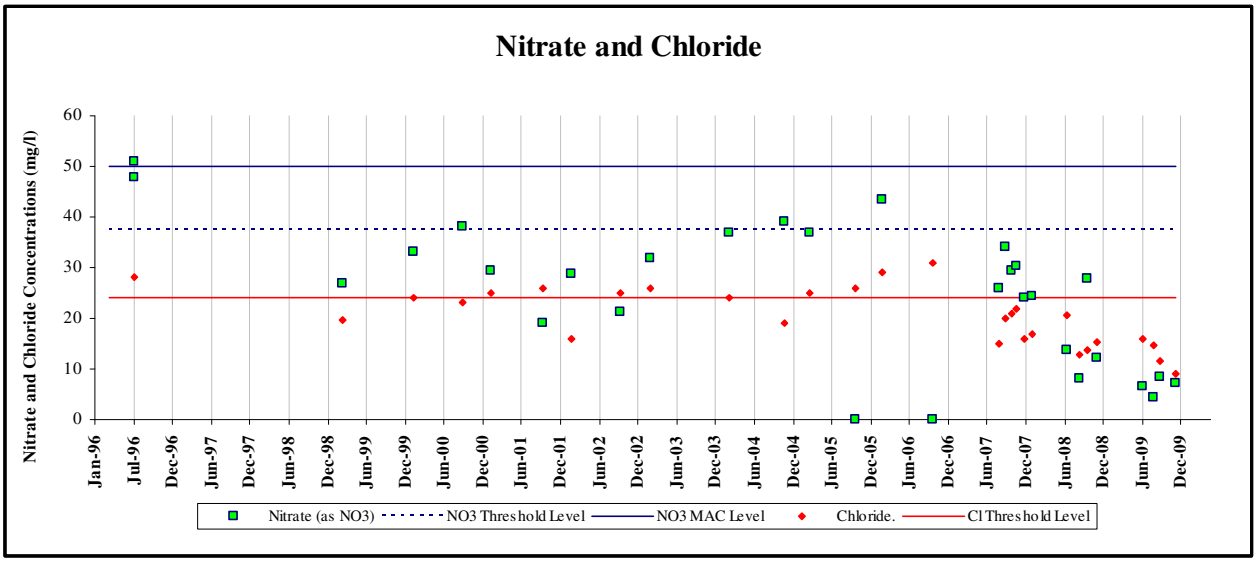

Figure 7 Key Indicators of Agricultural and Domestic Contamination: Nitrate and Chloride

- Turbidity exceeded the drinking water standard limit of 1 NTU on 10 occasions. This is likely due to the presence of very fine clay particles in the water which may occasionally be released from clay filled fractures in the bedrock.
- The sulphate, potassium, sodium, magnesium and calcium levels are within normal ranges. The potassium:sodium ratio is marginally above the threshold of 0.35, in 23 of the 30 analyses (Figure 8).
- The concentrations of iron and manganese are below the normal ranges except between November 2004 and October 2006. The highest levels were in October 2005 and October 2006 with respectively 3900 µg/l and 4100 µg/l of Iron and 1.6 mg/l and 0.9 mg/l of Manganese (Figure 8). The two highest concentrations correlate with lowest level of nitrate and highest level of ammonium and may be indicative of a historical contamination event

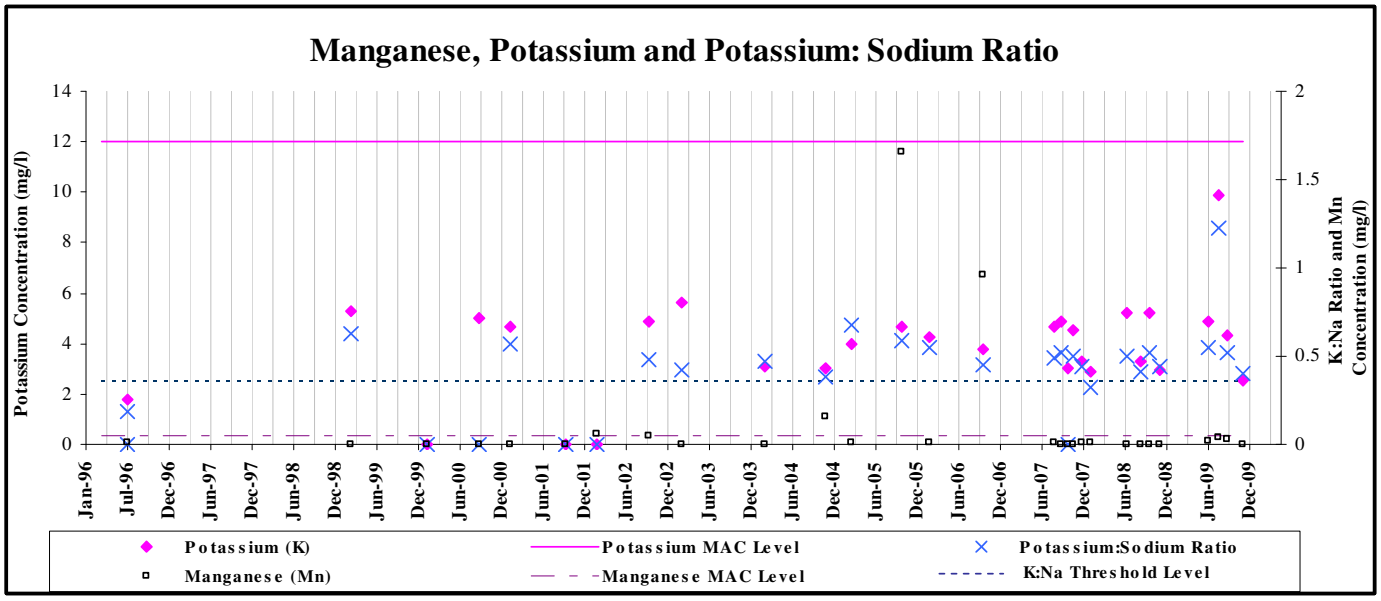

Figure 8 Key Indicators of Agricultural and Domestic Contamination: Manganese, Potassium and K/Na ratio

- The concentration of Nickel exceeded the MAC (20 µg/l) from Feb. 2003 to Oct. 2006 with an average of 35 µg/l. Since October 2006 the level decreased significantly and the mean is now 3 µg/l.
- Other trace metals were within either within the normal range for good quality drinking water or were not detected. Similarly, organic compounds and herbicides have not been detected.

Faecal coliforms have been detected frequently in the untreated water albeit at relatively low levels. It is possible that the origin of this contamination is the presence of cattle grazing in the field surrounding the compound. The nitrate levels average 24.2 mg/l, reflecting the presence of agricultural pressures and the high- extremely vulnerable nature of the aquifer within the local catchment. An improvement in water quality has been observed since 2008, with a significant reduction in nitrate and chloride. This improvement may be due in part to improved agricultural practices as a result of implementation of the Good Agricultural Practices Regulations over this period. However, the lower values may also reflect higher rainfall levels in 2008 and 2009.

9.4 Aquifer characteristics

Based on the GSI geology map, the boreholes abstract water from the Aghmacart Formation which is classified as part of the Dinantian Upper Impure Limestones Rock Unit Group. The aquifer in which the wells are located is classified by the GSI as a Locally Important aquifer which is moderately productive only in Local Zones (Ll), as indicated in Figure 9. The pumping well provides an average of 816 m^3/d. The yield is sustainable and the scheme has never had problems meeting demand. Given the high sustainable yields and shallow hydraulic gradients observed during pumping in the wells, it is possible that the boreholes are located in a dolomitised and/or karstic portion of the Aghmacart Formation and/or may be part of the Dinantian Pure Bedded Limestones, which are mapped approximately 1 km to the east.

The water table appears to be close to the surface, around 3 m bgl (see section 9.2) and the aquifer is considered to be unconfined across the catchment.

Groundwater flow occurs along bedding planes and through faults, fractures and fissures in the bedrock. As indicated in Section 7.2, the limestones in this area are often altered by the regional dolomitisation which has enhanced their mass permeability by creating additional void space. The yield observed during the pumping test, and ongoing sustainable pumping rates support this assumption. The 1996 pump test established that at an abstraction of 54 m^3/h the drawdown was only 2.22 m bgl, indicating a high specific capacity of 584 m^3/d/m.

The Templemore GWB Description, compiled by the GSI, indicates a transmissivity (T) range for Ll aquifers between 2 and 20 m^2/d, with median values occurring towards the lower end of the range. However, with the high pumping rates at this source, based on the pumping test carried out in 1996 on BH-1 and BH-2 (data are in Appendix 1) the transmissivity was calculated at 1,200 m^2/d.

Given the drawdown in the well is <30% of the assumed thickness of the aquifer, the CE Jacob Formula can be applied for unconfined conditions.

$$\text{Transmissivity (T)} = 0.183Q / \Delta s$$

Where: Q: pumped discharge rate (m^3/d) and Δs: change in drawdown per log cycle of t (m).

The interference between the two wells (located 2 m apart) is minimal (1 m drawdown for an abstraction of 54 m^3/h in BH-2) which confirms the high transmissivity within the formation locally.

The bedrock permeability for an Ll aquifer is expected to be low. The permeability is highest in the upper weathered portions of the aquifer, but generally decreases rapidly with depth. The permeability can be calculated by dividing the transmissivity by the saturated thickness of the aquifer. In this aquifer type the groundwater flow, in general, is concentrated in the upper 15 m of the aquifer. However the boreholes logs, which show that water strikes were encountered respectively at 31, 60 and 95 mbgl, indicate a groundwater flow deeper than 15m, and are associated with cavities, fractures and fissures.

Based on the available information it is assumed that the saturated thickness of the aquifer extends at least to the full depth of the boreholes i.e. 122 m. Therefore the bulk permeability (K) is estimated as follows:

Table 9-1: Permeability Range for BH1 and BH2

Parameter	Local Assumption
Transmissivity (m^2/d)	1,200
Permeability (m/d)	10

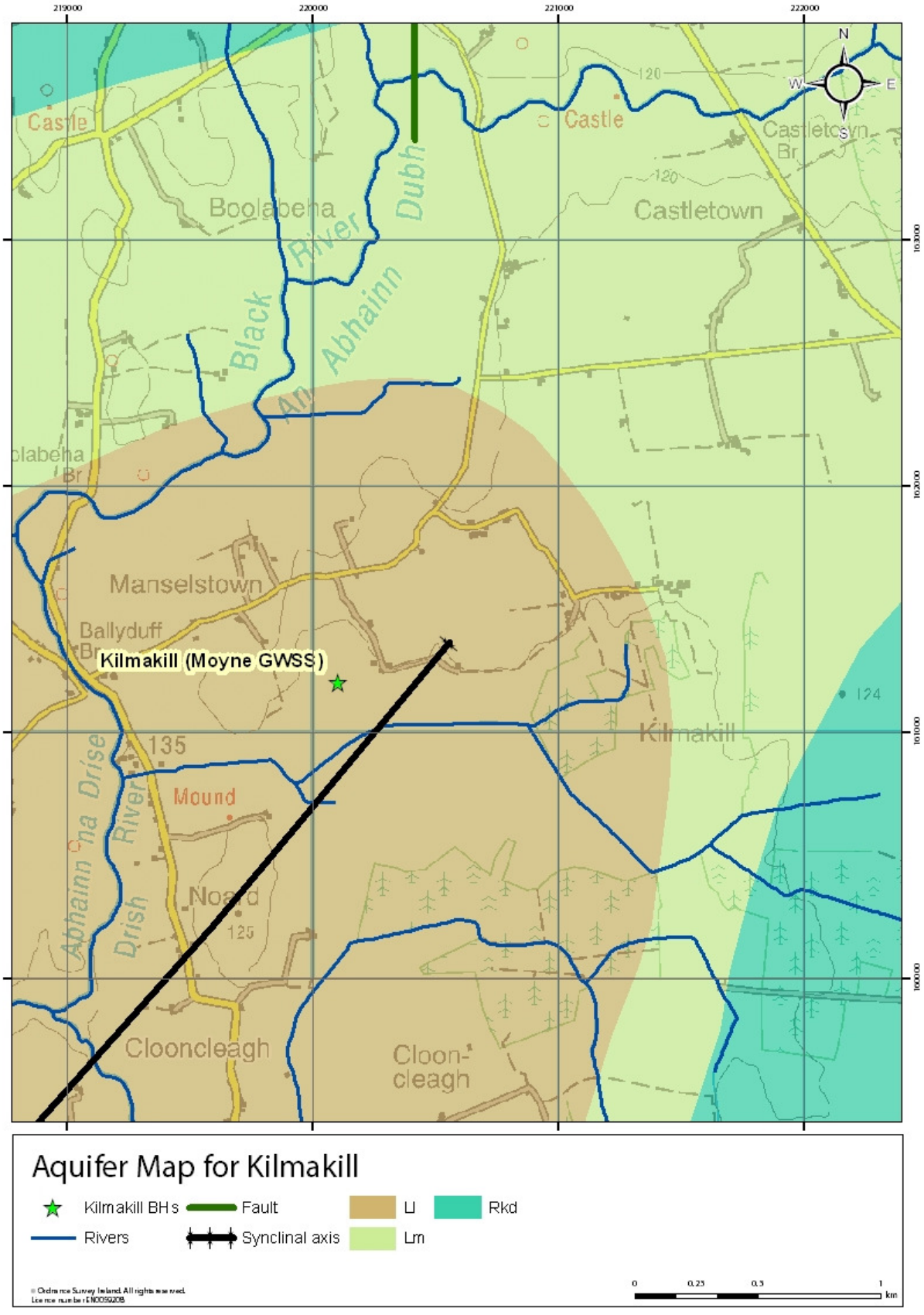

Figure 9 Aquifer map

The permeability for the aquifer is estimated to be 9.71 m/d. This is calculated by dividing the calculated transmissivity by the assumed aquifer thickness.

The velocity of water moving through this aquifer to the borehole has been estimated using Darcy's Law:

Velocity (V) = (K x Groundwater Gradient (i)) / porosity (n)

The natural gradient is estimated at 0.002 (Section 9.2). The effective fracture porosity in the Aghmagart Formation is estimated by the GSI, based on regional experience, at 0.02. That porosity value has been applied to the formation as part of the current assessment. Given the likely presence of dolomite and/or karst in the formation this porosity value may be slightly low. However a conservative approach has been adopted for the purpose of this assessment.

Table 9-2: Estimated Velocity for BH1 and BH2

	Velocity (m/d)
Local Effective Porosity (2%) Local K Assumption (10 m/d)	1

The velocity of groundwater moving through the aquifer is estimated as 1 m/d. The aquifer parameters are summarized in Table 9-3.

Table 9-3: Indicative Parameters for the Aghmacart Formation from the Dinantian Upper Impure Limestones in Kilmakill

Parameters	Source of Data	BH1/BH2
Transmissivity (m^2/d)	Calculated (based on pumping test data)	1,200 m^2/d
Permeability (m/d)	estimated from T value assuming saturated thickness is the full depth of the boreholes	10
Effective Porosity	Assumed (based on GSI based on regional experience)	2%
Groundwater gradient	Assumed based on topography and field observations	0.002
Velocity (m/d)	calculated based on above	1

10 Zone of Contribution

The Zone of Contribution (ZOC) is the complete hydrologic catchment area to the source, or the area required to support an abstraction from long-term recharge. The size and shape of the ZOC is controlled primarily by (a) the total discharge, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability and (d) the recharge in the area. This section describes the conceptual model of how groundwater flows to the source, including uncertainties and limitations in the boundaries, and the recharge and water balance calculations which support the hydrogeological mapping techniques used to delineate the ZOC.

10.1 Conceptual model

Groundwater flows in a south-westerly direction towards the source and beyond to the Black River (Figure 10). The primary aquifer is the Dinantian Impure Limestone (Aghmacart Formation) which is mapped as a Locally Important aquifer; Moderately Productive only in Local Zones (Ll). In this area, the high well yields, high transmissivity, high specific capacity, shallow gradients and the likely dolomitisation and karstification that have occurred, all provide evidence that the local zones are sufficiently well developed to provide a sustainable source. The aquifer is also underlain by a slightly more productive limestone unit (Dinantian Pure Bedded Limestones; Crosspatrick Fm) which may be contributing to the local groundwater resource. The aquifer is unconfined, has High to Extreme vulnerability over much of the area, and is likely to be recharged locally, through the moderately permeable, often very thin subsoils. This is reflected in the water quality results which show the frequent presence of faecal bacteria in the untreated water. A schematic of the conceptual model is shown in Figure 10.

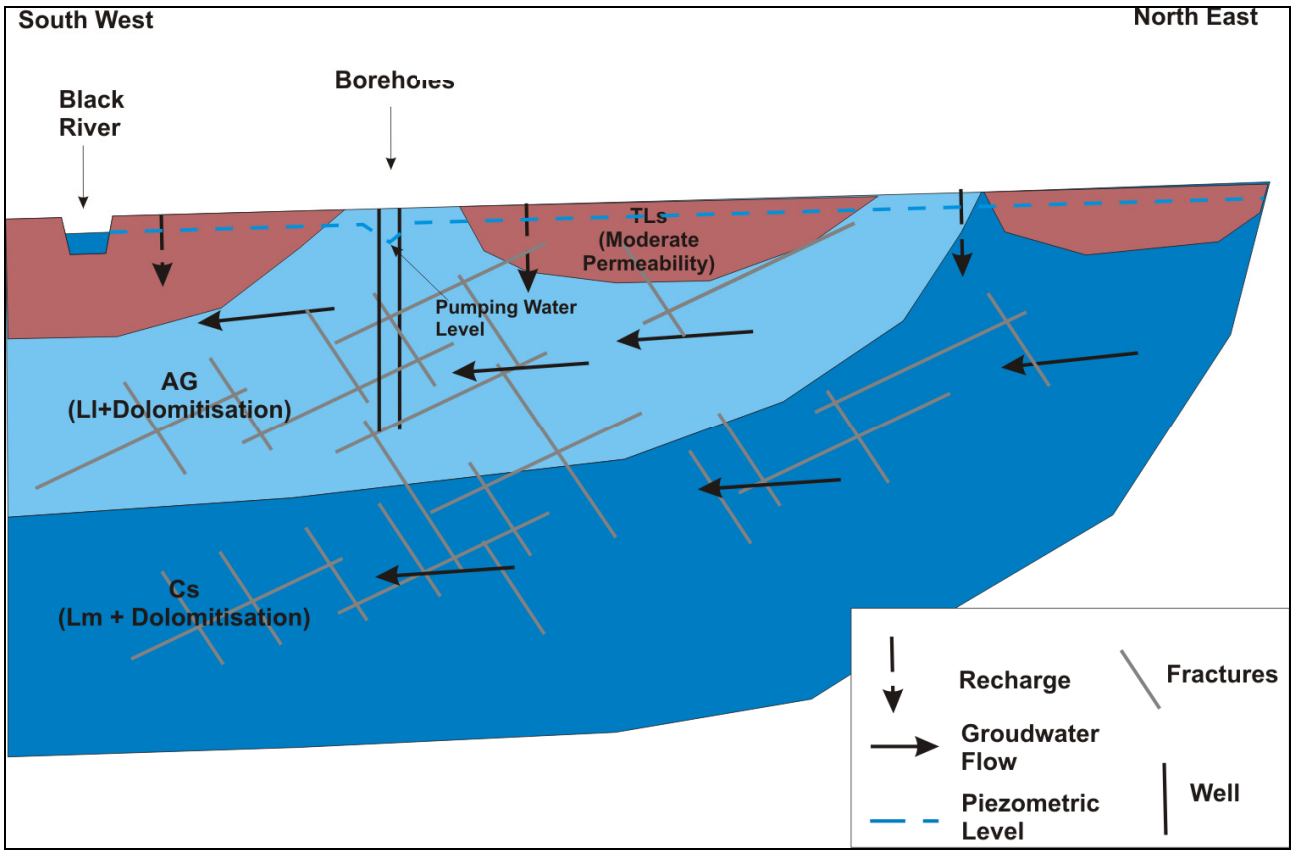

Figure 10 Conceptual model

10.2 Boundaries of the ZOC

The boundaries of the area contributing to the source are considered to be as follows (Figure 11):

The Northern, Western and Eastern boundaries are difficult to delineate precisely because of the relatively gentle gradient across the area (0.002). The boundaries are primarily based on the topography, conceptualised groundwater flow-lines, which flow to the southwest in the direction of the Black River, and the size of the estimated ZOC using the recharge and water balance equations (see next section).

The Southern boundary is based on proximity to the stream to the south, which is considered to be a hydraulic boundary to flow toward the wells.

The Southwestern boundary – the downgradient boundary is the maximum downgradient distance from which groundwater can be drawn to the borehole and it is based on the uniform flow equation (Todd, 1980).

$$xL = Q / (2\pi * T * i) \text{ where:}$$

where Q is the daily pumping rate +/- X%, T is Transmissivity (taken from aquifer characteristics) and i is gradient.

Given the pumping rate is 816 m^3/d, the transmissivity is 1200 m^2/d and the hydraulic gradient is 0.002, the approximate maximum downgradient distance is 54 m. In general, the down-gradient distance for a Ll aquifer is estimated to be around 60 m (approximate downgradient distance estimated by GSI for ZOC delineation). Therefore, the conservative distance of 60 m (instead of 55 m) has been applied.

10.3 Recharge and Water Balance

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. The recharge rate is generally estimated on an annual basis, and assumed to consist of input (i.e. annual rainfall) less water loss prior to entry into the groundwater system (i.e. annual evapotranspiration and runoff). The estimation of a realistic recharge rate is important in source protection delineation, as it will dictate the size of the ZOC to the source (and therefore the Outer Source Protection Area).

Given the high transmissivity of this aquifer locally, the recharge aquifer cap of 200 mm normally applied to an Ll aquifer has not been applied here. At Kilmakill therefore, the main parameters involved in recharge rate estimation are: annual rainfall; annual evapotranspiration and a recharge coefficient. The recharge is estimated as follows.

Potential recharge is equivalent to 506 mm/yr i.e. (Annual Effective Rainfall as outlined in Section 6).

Actual recharge has been estimated to be 303 mm/yr; this value is based on the following observations:

The majority of the ZOC (70%) is mapped as High Vulnerability, as the bedrock is overlain by moderate permeability subsoils and well drained soils. Guidance document GW5 recommends a recharge coefficient in the range of 0.25 to 0.80 be applied for these conditions, with an inner range of 0.60 (IWWG, 2005). The low drainage density in the study area indicates that recharge occurs readily. The shallow slope of the sub-catchment containing the source is likely to promote a small degree of runoff. It is considered that an inner range coefficient of 0.60 can be applied in this case.

The other part of the ZOC (30%), near the wells and at the eastern end of the catchment, is classified as Extreme Vulnerability with the bedrock either outcropping and/or close to the surface (11%); or overlain by thin well drained soils (12%); or overlain by peat (7%). Three separate recharge coefficients from Guidance Document GW5 have been assigned to these areas: 0.85 where rock is close to or at the surface, i.e no subsoil; 0.60 where thin well draining subsoil overlies the bedrock; and a value of 0.30 where peat overlies the thin subsoil.

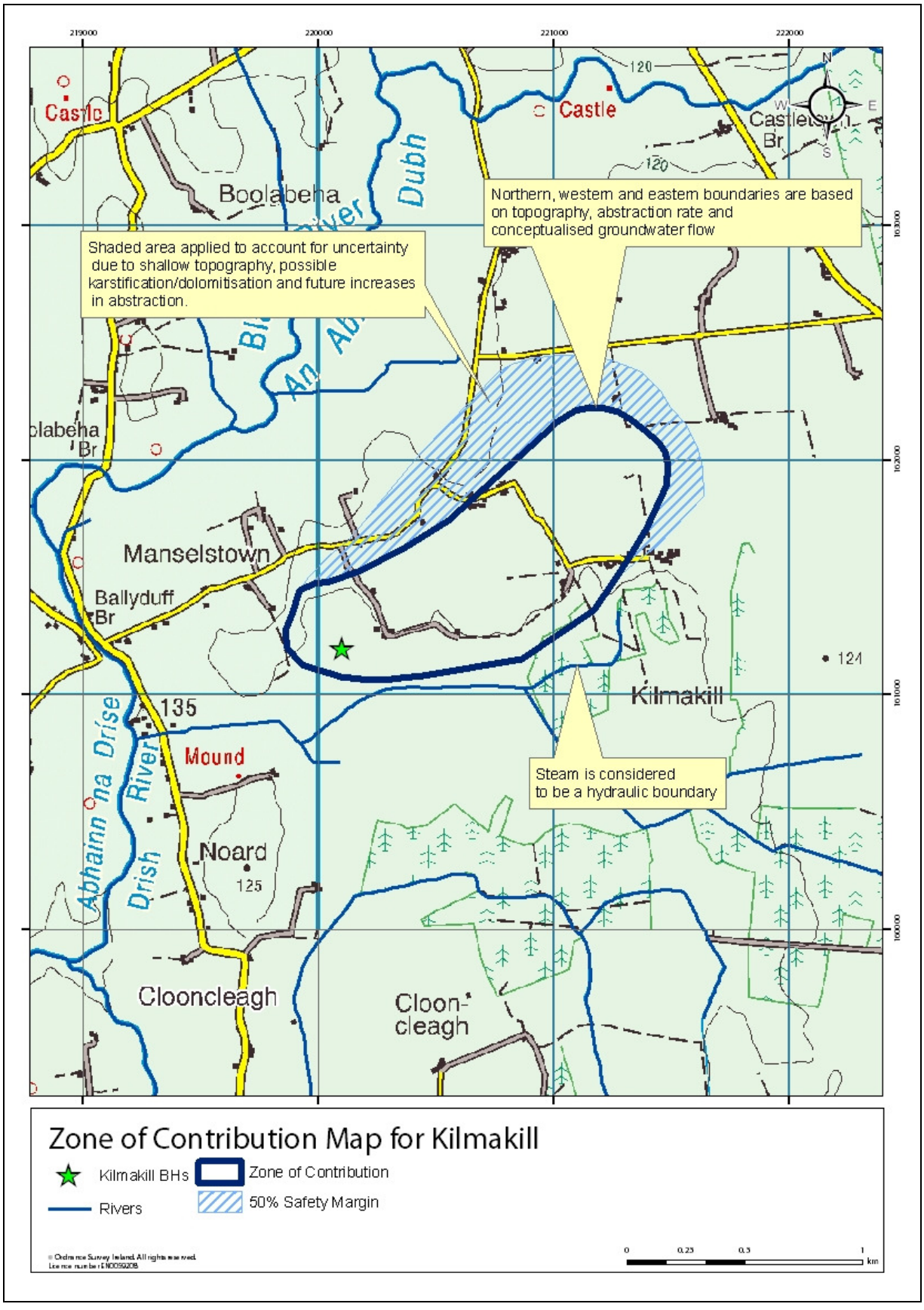

Figure 11 Zone of contribution

Runoff losses in the total catchment are assumed to be 40% of the potential recharge (effective rainfall). This value is based on an assumption of c.42% runoff for 30% of the area (extreme vulnerability – rock close to surface) and 40% runoff for 70% of the area (H vulnerability). The bulk recharge coefficient for the area is therefore estimated to be 60%.

Runoff losses: 204 mm. Runoff losses are assumed to be 40% of potential recharge.

These calculations are summarised as follows:

Average annual rainfall (R)	1000 mm
Estimated P.E.	494 mm
Estimated A.E. (95% of P.E.)	469 mm
Effective rainfall	506 mm
Potential recharge	506 mm
Recharge coefficient	82 % of the area at 0.6 7 % of the area at 0.3 11 % of the area at 0.85
Bulk recharge coefficient	60%
Runoff losses	40%
Assumed Recharge	**303 mm***

*Note the cap is not applied due to the presence of high permeability zones

The water balance calculation states that the recharge over the area contributing to the source, should equal the discharge at the source. At a recharge of 303 mm/yr, an average yield of 816 m^3/day would require a recharge area of around 1 km^2. This is the area of the ZOC described above, and shown in Figure 11.

To allow for daily variations in abstraction, a possible increase in demand, and for the expansion of the ZOC during dry weather periods, the GSI recommends increasing the abstraction rate by 50% for the purposes of delineating the ZOC. Therefore, assuming an abstraction of 1632 m^3/d, the size of required recharge area would be increased to 1.50 km^2. The boundaries of both ZOC options are shown in Figure 11.

11 Source Protection Zones

The Source Protection Zones are a landuse planning tool which enables an objective, geoscientific assessment of the risk to groundwater to be made. The zones are based on an amalgamation of the source protection areas and the aquifer vulnerability. The source protection areas represent the horizontal groundwater pathway to the source, while the vulnerability reflects the vertical pathway. Two source protection areas have been delineated, the Inner Protection Area and the Outer Protection Area.

The Inner Protection Area (SI) is designed to protect the source from microbial and viral contamination and it is based on the 100-day time of travel to the supply (DELG/EPA/GSI 1999). Based on the indicative aquifer parameters presented in section 9.4, the groundwater velocity is 1 m/d, and hence the 100-day time of travel distance is 100 m. The Inner Protection Area is illustrated in Figure 12.

The Outer Protection Area (SO) encompasses the entire zone of contribution to the source. In order to take the more conservative approach, the ZOC based on the 50% increased yield is adopted, i.e. 1.47 km^2.

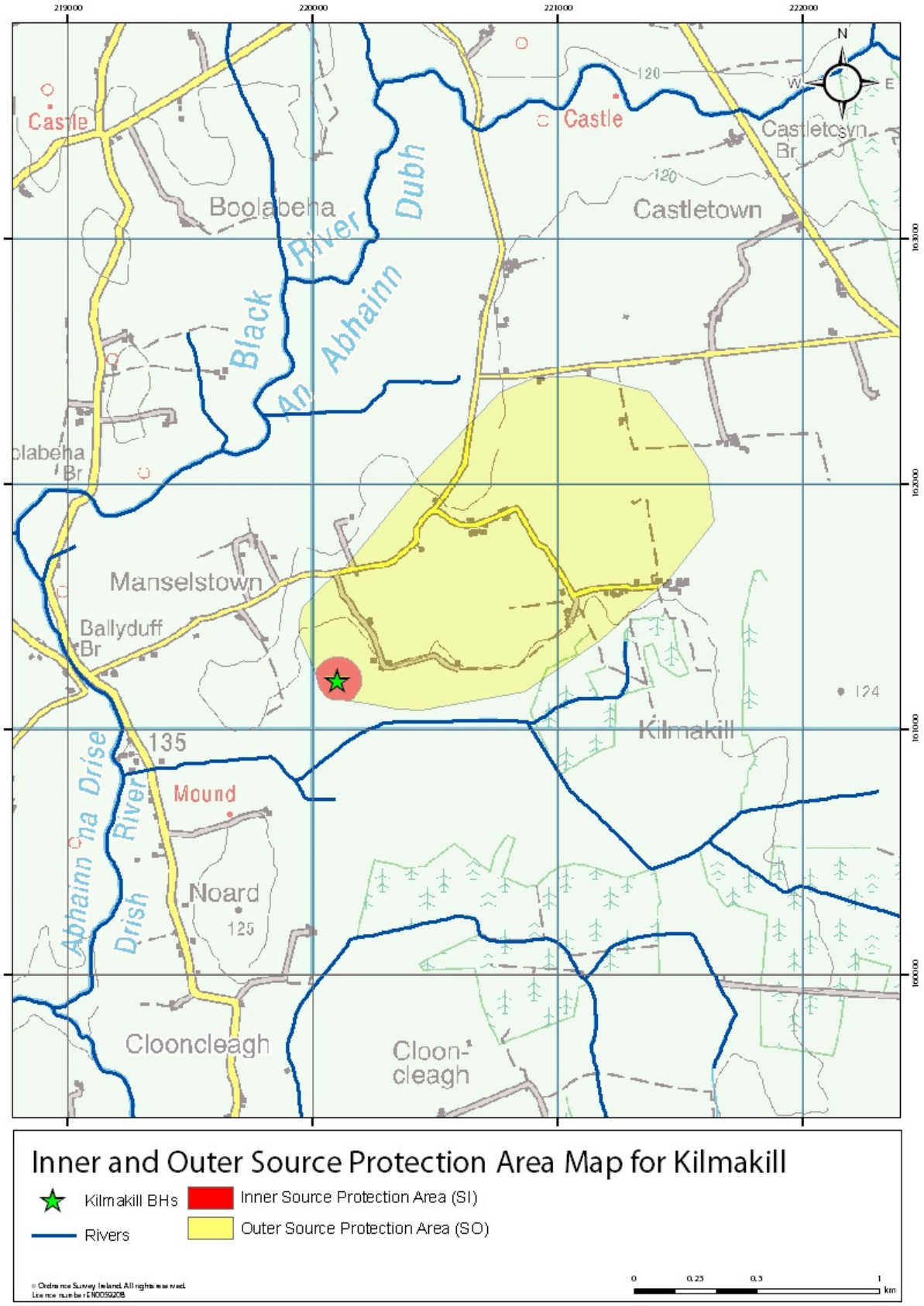

Figure 12: Inner and Outer Source Protection Areas

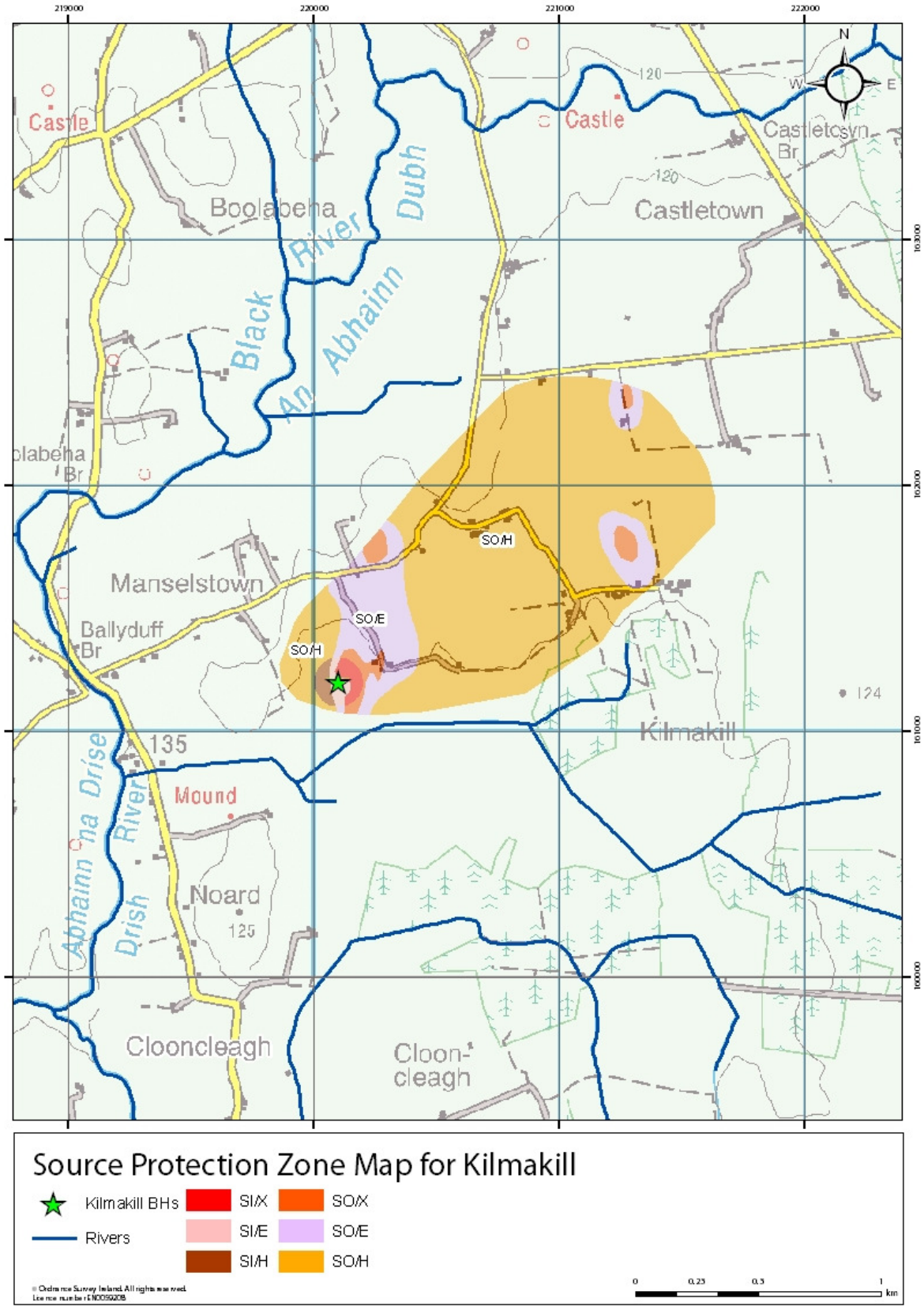

Figure 13 Source Protection Zones

The groundwater Source Protection Zones are shown in Figure 13 and are listed in Table 11-1. They include SI/X, SI/E and SI/H, although the large majority of the ZOC is designated as SO/H.

Table 11-1 Source Protection Zones

Source Protection Zone		% of total area (km^2)
SI/X	Inner Source Protection area / ≤1 m subsoil	0.80% (0.012 km2)
SI/E	Inner Source Protection area / <3 m subsoil	0.61% (0.009 km^2)
SI/H	Inner Source Protection area / High vulnerability	0.65% (0.010 km^2)
SO/X	Outer Source Protection area / ≤1 m subsoil	2.54% (0.039 km^2)
SO/E	Outer Source Protection area / <3 m subsoil	13.93% (0.211 km^2)
SO/H	Outer Source Protection area / High vulnerability	81.46% (1.234 km^2)

12 Potential pollution sources

The two boreholes are in a securely fenced and locked compound and are sealed to protect against the inflow of contaminated surface or shallow subsurface water. The ground surface in the compound comprises granular fill. Given the high level of wellhead protection and the location of the boreholes, the potential risk for contamination as a result of surface spills in the immediate vicinity of the well heads is very low.

The landuse within the Inner Source Protection Area is primarily pastureland for grazing animals. The main potential microbial pollution sources are considered to be the presence of cattle grazing in the field surrounding the compound. Faecal coliforms have been detected frequently in the untreated water, albeit at relatively low levels. Given the predominantly Extreme vulnerability within the Inner Source Protection Area, the potential risk from cryptosporidium and viruses is high.

The majority of land within the Outer Source Protection Area is agricultural grassland and the dominant farm activity is dairy farming. There are 3 farms located within the ZOC. The main potential pollution sources associated with farming activities are animal slurry storage areas, farmyard washings, grazing animals and landspreading of agricultural waste. The possible impacts to the water quality of the public supply associated with these activities within its Outer Source Protection Area are elevated levels of ammonia, nitrate, phosphate, chloride, potassium, BOD, COD, TOC and pesticides. With the exception of the nitrate levels (average 24.2 mg/l), these parameters are not generally elevated in the untreated water supply. Moreover, an improvement in water quality has been observed since 2008, with a significant reduction in nitrate and chloride. This improvement may be due in part to improved agricultural practices as a result of implementation of the Good Agricultural Practices Regulations over this period. Finally, there are 2 (2 No.) third class roads in the north and the east of the ZOC. The main potential contaminants from this source are surface water runoff contaminated with hydrocarbons and metals. However, the low traffic density locally indicates that the risk of such contamination is low.

In summary, given the land use, the Extreme vulnerability rating within the SI and the existing water quality data with frequent detection of faecal coliforms at the source, albeit at generally low levels, there is a need for a cryptosporidium filter to be incorporated into the treatment system.

13 Conclusions

The Moyne Group water Supply Scheme (Private) comprises two boreholes installed in 1996. The boreholes abstract water from the Aghmacert Limestone Formation. The aquifer is classified as a Locally Important Aquifer that is Moderately Productive only in Local Zones (Ll). The wells provide 816 m^3/d and are pumped individually in alternative months. This pumping rate has been sustainable since the wells were commissioned in 1997.

The groundwater vulnerability with the Inner Source Protection Area is Extreme with rock at or very close to the surface in places. This is reflected in the groundwater quality at the source as faecal coliforms are regularly detected in the untreated water. Nitrate and chloride levels above levels indicative of potential contamination have been detected in the past but have significantly improved since 2008. This may be due in part to improved agricultural practices as a result of implementation of the Good Agricultural Practices Regulations or due to higher rainfall levels in 2008 and 2009. Over the remainder of the area, the vulnerability is High and other water quality indicators are generally good.

The ZOC encompasses an area of 1.47 km^2 which incorporates a 50% increase in the pumping rate as recommended by the GSI. The Source Protection Zones are based on the current understanding of the groundwater conditions and the available data. Additional data obtained in the future may require amendments to the protection zone boundaries.

14 Recommendations

A cryptosporidium barrier should be provided to mitigate risk of microbial contamination.

15 References

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APPENDIX 1

Report 'Well test at Stapletons, Kylemakill, Moyne, Thurles, Co. Tipperary – Test Report'

(Patrick Briody and Sons- Aquadril Services, 1996)

(D)

Patrick Briody & Sons — Aquadril Services

Drilling & Water Services

Telephone: (045) 24360, Fax. (045) 24360, Mobile (088) 589313,

Approved Quality System

Grove House,
Ballinrakan,
Rathangan,
Co. Kildare

LISHEEN PROJECT

Well Test at Stapletons,
Kylemakill, Moyne, Thurles, Co. Tipperary

TEST REPORT

E.P.S. Ltd

Sheet for pumping test

Borehole at: Lisheen No:						PUMPING TEST MEASUREMENTS	
County & 6" sheet No:				Drawdown ☐		Recovery ☐	
Date: 01/07/96				Pumping well ☐		Observation Well ☐	
Weather:				Test conducted by: Vincent McNamara		Distance from pumping well:	
Time	Elapsed time min/hr	Water level m	Draw-down m	Meter reading gallons	Pumping rate g/hr	Remarks (e.g. pump behaviour, water temp, water quality etc)	Observation Well
3.45pm	0	3.17m		9,886			
3.46	1	3.65		9,888	6,900		3.18
	2	3.62					
	3						
3.49	4	3.65		9,891	6,000		
	5						
	6	3.70					
	7						
3.58	8	3.65		9,894	6,000		
	9						
3.50	10	3.65		9,897			
3.52	12	3.66		9,900	6,000		
	14						
4.01	16	3.66		9,902	6,000		
4.03	18	3.69		9,904	6,000		
4.05	20	3.68		9,904	6,000	Water clear	
4.10	25	3.72		9,911	6,000	118mm/120mm weir	
4.15	30						
4.20	35	3.77		9,921	6,000		
4.25	40	3.77		9,927			
4.30	45	3.775		9,932	6,000		3.42
4.35	50	3.77		9,937			
4.40	55	3.78		9,942.5	6,000		3.45
4.45	60	3.775		9,947	6,000		
5.00	75	3.79		9,963			
5.15	90	3.79		9,977		120mm weir	
	105					Water clear	
	2 hrs						
	2½hrs						

E.P.S. Ltd
Sheet for pumping test

Borehole at: Lisheen No:						PUMPING TEST MEASUREMENTS	
County & 6" sheet No:				Drawdown ☐		Recovery ☐	
Date: 01/07/96				Pumping well ☐		Observation Well ☐	
Weather: Dry/Cloudy				Test conducted by: Vincent McNamara		Distance from pumping well:	
Time	Elapsed time min/hr	Water level m	Draw-down m	Meter reading gallons	Pumping rate g/hr	Remarks (e.g. pump behaviour, water temp, water quality etc)	Observation Well
5.20pm	0	3.80		9,982.5	6,000	Water clear	
5.21	1	4.13		9,985.5	8,000		
	2						
	3						
5.24	4	4.215			8,700		
5.25	5	4.34		9,989	9,000		
5.26	6	4.33		9,991	9,000		
5.27	7						
5.28	8	4.34		9,994.5			
5.29	9						
5.30	10	4.34	.54	9,998	9,000		
5.32	12						
5.34	14	4.36		10,003	9,000		3.67m
5.36	16	4.36		10,006.5	9,000		
5.38	18	4.37		10,010	9,000		
5.40	20	4.37		10,013	9,000		
5.45	25	4.38		10,020	9,000		
5.50	30	4.40		10,628.5	9,000		
5.55	35						
6.00	40	4.4	.6	10,042	9,000		
6.05	45	4.4		10,050	9,000	140mm weir level	
6.10	50	4.4		10,057.5	9,000		3.72
6.15	55	4.4	.6	10,065.5		Well	
6.20	60	4.4		10,073	9,000		3.73
6.35	75	4.44		10,094.5			3.74
6.50	90	4.45		10,118			3.75
	105						
	2 hrs						
	2½hrs						

E.P.S. Ltd
Sheet for pumping test

Borehole at: Lisheen No:						PUMPING TEST MEASUREMENTS	
County & 6" sheet No:				Drawdown ☐		Recovery ☐	
Date: 01/07/96				Pumping well ☐		Observation Well ☐	
Weather: Drizzly				Test conducted by: Vincent McNamara		Distance from pumping well:	
Time	Elapsed time min/hr	Water level m	Draw-down m	Meter reading gallons	Pumping rate g/hr	Remarks (e.g. pump behaviour, water temp, water quality etc)	Observation Well
6.50pm	0	4.45		10,118			
	1						
	2	4.65		10,123	10,200		
	3						
	4						
6.55	5	4.77		10,127.5	10,800		
	6						
6.57	7	4.88			11,100		
6.58	8	4.88		10,133			
	9						
7.00	10	5.00		10,137			
7.02	12	5.01		10,141	11,700		
7.04	14	5.02		10,143			
7.06	16	5.10		10,147.5	12,000		4.0
6.08	18	5.10		10,151	12,000		
7.10	20	5.12		10,155	12,000		
7.15	25	5.15		10,166	12,000		
7.20	30						
7.25	35	5.22		10,187			
7.30	40	5.22		10,195	12,000		4.0
7.35	45	5.23		10,205			
7.40	50	5.235		10,215			4.06
7.45	55	5.26		10,225	12,000		
7.50	60	5.26		10,235			
8.05	75						
8.20	90						
9.35	105	5.37		10,450			
	2 hrs						
10.10	2½hrs	5.41		10,517	12,000		4.22m

E.P.S. Ltd
Sheet for pumping test

Borehole at: Lisheen No:						PUMPING TEST MEASUREMENTS	
County & 6" sheet No:				Drawdown ☐		Recovery ☐	
Date: 02/07/96				Pumping well ☐		Observation Well ☐	
Weather: Dry				Test conducted by: Vincent McNamara		Distance from pumping well:	
Time	Elapsed time min/hr	Water level m	Draw-down m	Meter reading gallons	Pumping rate g/hr	Remarks (e.g. pump behaviour, water temp, water quality etc)	Observation Well
12.20am	0	5.42m		10,773	12,000		4.275
	1						
3.10	2	5.51		11,107	12,000		4.34
	3						
6.10	4	5.59		11,459			4.39
	5						
9.10	6	5.62		11,816	12,000		4.43
	7					160mm weir level	
11.10	8	5.66		12,051	12,000		4.46
	9						
2.10 PM	10	5.65		12,169	12,000		4.47
1.15	12	5.67		12,297			4.48
2.10	14	5.67		12,405			4.48
	16						
3.15	18	5.67		12,534			4.50
4.15	20	5.70		12,651			
	25						
5.30	30	5.70		12,798			4.51
	35						
8.00	40	5.70		13,094	12,000		4.54
	45					Water cristal clear	
	50						
9.30	55	5.70		13,271			4.55
	60						
11.30	75	5.76		10,571	12,000		4.57
	90						
	105						
	2 hrs						
	2½hrs						

E.P.S. Ltd
Sheet for pumping test

Borehole at: Lisheen No:						PUMPING TEST MEASUREMENTS	
County & 6" sheet No:				Drawdown ☐		Recovery ☐	
Date: 03/07/96				Pumping well ☐		Observation Well ☐	
Weather: Dry				Test conducted by: Vincent McNamara		Distance from pumping well:	
Time	Elapsed time min/hr	Water level m	Draw-down m	Meter reading gallons	Pumping rate g/hr	Remarks (e.g. pump behaviour, water temp, water quality etc)	Observation Well
	0						
6.00am	1	5.80		14,275			4,62
	2						
9.30	3	5.84		14,187			4,65
	4						
2.45pm	5	5.85		15,307			4,67
	6						
3.45	7	5.85		15,426			4,68
	8						
5.45	9	5.88		15,662			
7.45	10	5.88		15,897			4.70
	12						
9.45	14	5.89		16,133			4.71
	16						
	18						
	20						
	25						
	30						
	35						
	40						
	45						
	50						
	55						
	60						
	75						
	90						
	105						
	2 hrs						
	2½hrs						

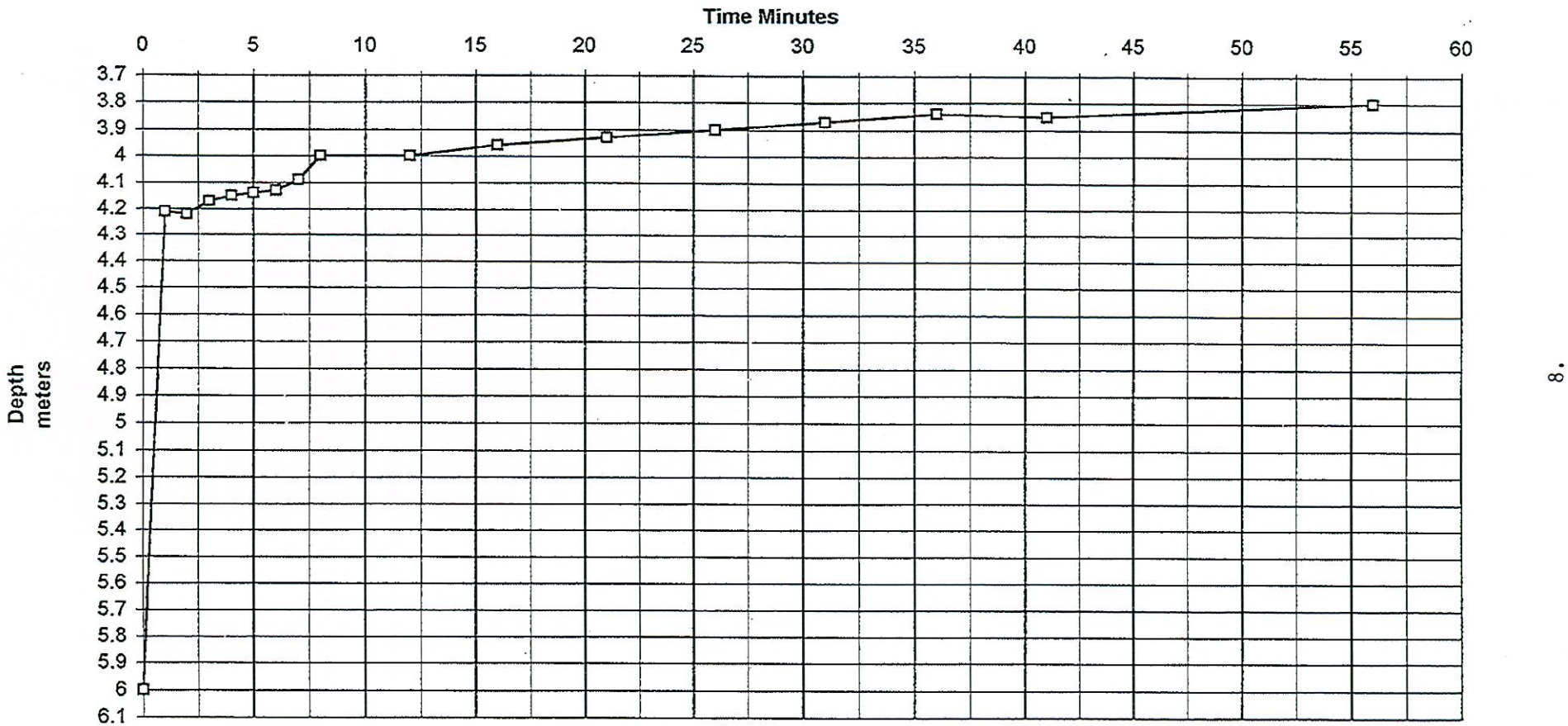
E.P.S. Ltd
Sheet for pumping test

Borehole at: Lisheen No:						PUMPING TEST MEASUREMENTS	
County & 6" sheet No:				Drawdown ☐		Recovery ☐	
Date: 04/07/96				Pumping well ☐		Observation Well ☐	
Weather: Damp				Test conducted by: Vincent McNamara		Distance from pumping well:	
Time	Elapsed time min/hr	Water level m	Draw-down m	Meter reading gallons	Pumping rate g/hr	Remarks (e.g. pump behaviour, water temp, water quality etc)	Observation Well
	0						
12.05am	1	5.89		16,410	12,000		4.93
	2						
8.30am	3	5.98		17,400			4.78
	4						
10.30	5	5.98		17,638			4,79
	6						
12.30	7	5.98		17,873			4.80
	8						
	9						
	10						
2.30	12	6.0		18,110			4,81
	14						
3.30	16	6.0		18,226	12,000		4,815
	18						
3.45	20	6.0m		18,256			4,82
	25						
	30						
	35						
	40						
	45						
	50						
	55						
	60						
	75						
	90						
	105						
	2 hrs						
	2½hrs						

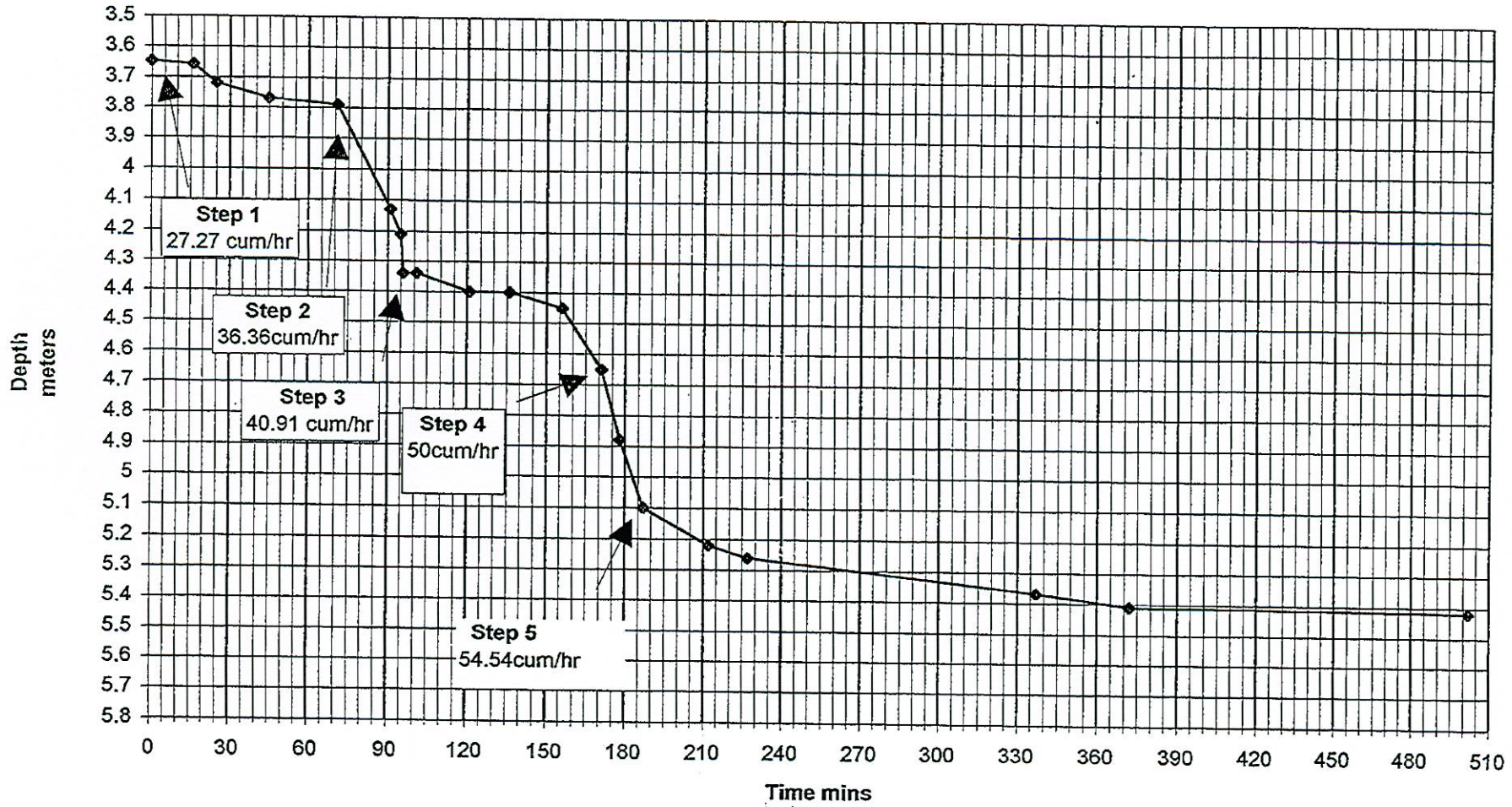
E.P.S. Ltd
Sheet for pumping test

Borehole at: Lisheen No:						PUMPING TEST MEASUREMENTS	
County & 6" sheet No:				Drawdown ☐		Recovery ☑	
Date: 04/07/96				Pumping well ☐		Observation Well ☐	
Weather:				Test conducted by: Vincent McNamara		Distance from pumping well:	
Time	Elapsed time min/hr	Water level m	Draw-down m	Meter reading gallons	Pumping rate g/hr	Remarks (e.g. pump behaviour, water temp, water quality etc)	Observation Well
3.45pm	0	6.0m		18,256			4.82m
3.46	1	4.21					
3.47	2	4.22					4.20m
3.48	3	4.17					
3.49	4	4.15					4.15m
3.50	5	4.14					
3.51	6	4.13					4.12m
3.52	7						
3.53	8						
3.54	9	4.09					4.09m
3.55	10						
3.57	12	4.0					4.03m
3.59	14						
4.01	16	4.0					3.99m
	18						
4.05	20	3.96					3.96m
4.10	25	3.93					3.93m
4.15	30	3.90					3.90m
4.20	35	3.87					3.88m
4.25	40	3.84					3.87m
4.30	45	3.85					3.85m
4.35	50						
4.40	55						
4.45	60	3.80					3.82m
	75						
	90						
	105						
	2 hrs						
	2½hrs						

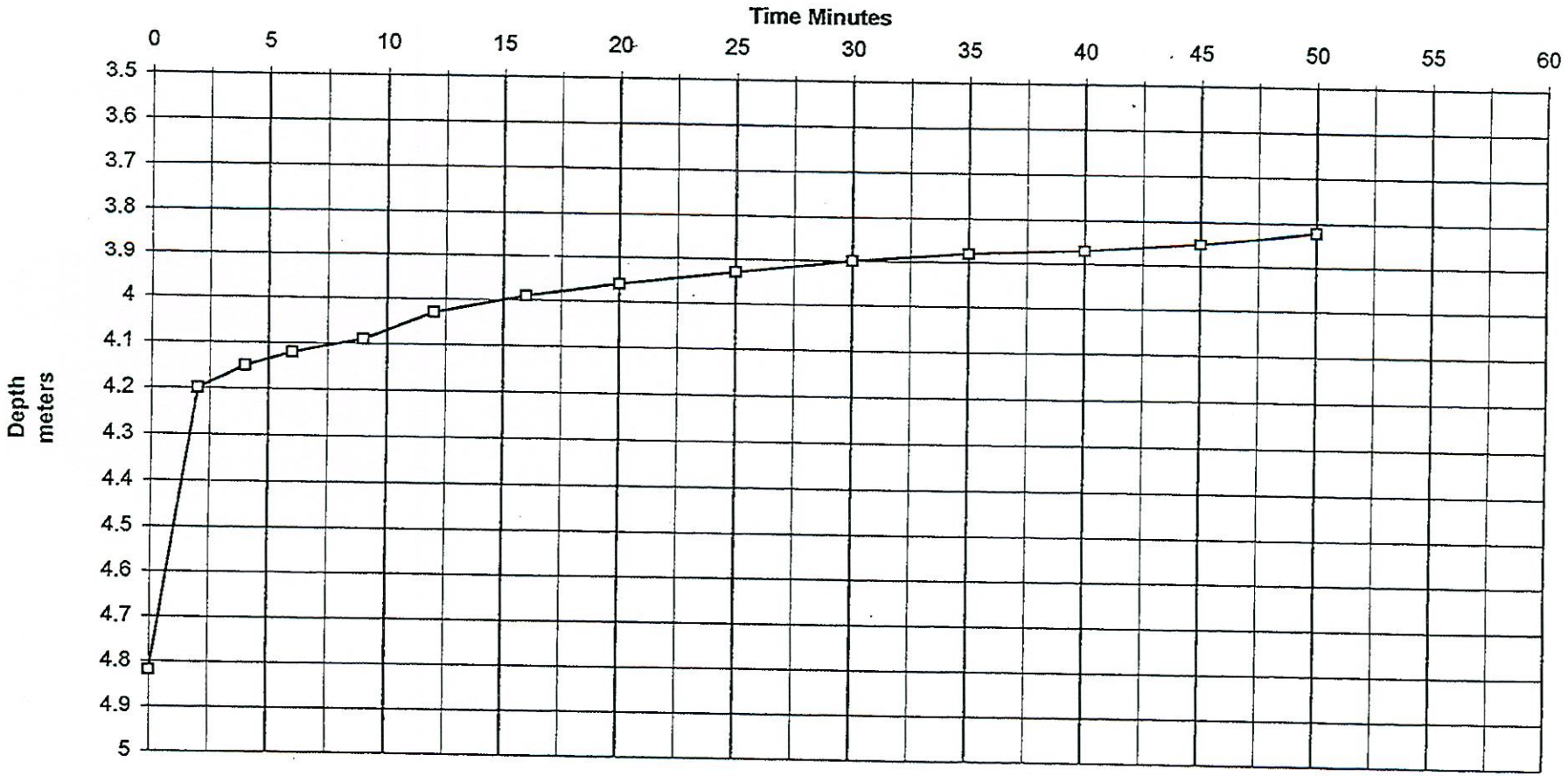
Lisheen Project - 2nd Well Test 04.07.96
Borehole Recovery



Lisheen Project - 2nd Well Test
Borehole Step Test



Lisheen Project - 2nd Well Test 04.07.96
Observation Borehole Recovery



Description of completed Boreholes

Following successful completion of a trial borehole at the site, two adjacent production boreholes were constructed as follows:

The boreholes were drilled at a diameter of 250 mm to a depth of 122 m. On completion of drilling the boreholes were airlifted to remove fine material until the water flowed clear.

On completion of airlifting a 200 mm nominal diameter PVC casing string was installed to the full depth of the boreholes. The casing string was comprised of an end cap followed by 40 m of factory slotted PVC screen (with a maximum slot size of 1 mm). The remainder of the casing was plain PVC casing.

After installation of the casing string the annulus between the casing and the borehole wall was filled to a depth of 80 m below ground level with clean, round pea gravel with a range of diameters of between 5 and 20 mm. After installing the pea gravel the boreholes were surged using air lifting from above the screen and the level of the pea gravel re-established to 80 m below ground level as it settles. The boreholes were developed until the level of the pea gravel stabilised and the water came clear and free of silt. On completion of development a 2 m thick sand plug was installed by tremmie pipe on top of the gravel.

The annulus between the casing and borehole wall was filled with cement trout from the top of the sand plug to a depth of 5 m below ground surface. The grout was placed by pumping through a tremmie pipe to the top of the placed grout. The grout was allowed to stand overnight and topped up to a depth of 5 m below ground level when it had settled.

The top of the boreholes was completed within an inspection chamber of sufficient size to provide a minimum clearance of 300 mm around the casing. The depth of the chamber was sufficient to allow the casing to stand a minimum of 300 mm above the case of the chamber and allowed a minimum of 300 mm clearance to the top of the chamber. The chamber was constructed so as to be water tight. The chamber was topped with a water tight load bearing manhole cover. The annulus between the borehole wall and the casing was filled from 5 m below ground level to the base of the inspection chamber. A standard NP16 flange was attached to the top of the casing and a blank top plate fitted. The top plate has installed at its centre a threaded plug of diameter not less than 60 mm to allow access for an electronic water level measuring device and water sampling equipment.

Test pumping was then carried out and the following results obtained:-

ATTACHMENT
No. 2

Borehole Water Quality Results

Moyne Group Water Scheme
Planning Application

Analysis Report

16 JUL 1996

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LABORATORIES

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Pharmaceutical · Chemical · Food · Environmental

Ms Margaret Stokes.
Minorco Lisheen Ltd.
Lisheen Site Office,
Kilclonagh,
Thurles,
Co Tipperary.

Sample Type : Water

Received Date : 02/Jul/96
Analysis End Date : 12/Jul/96

Lab Number :	963613
Batch Number :	1st Day Pump Test Lisheen 02/07/96 12.30

Test Parameter	Result	Test Method
*Iron (as Fe)	36ug/L	ICPAES
*Manganese (as Mn)	ND<5ug/L	ICPAES
*Zinc (as Zn)	126ug/L	ICPAES
*Lead (as Pb)	ND <10ug/L	ICPAES
*Calcium (as Ca)	122mg/L	ICPAES
*Magnesium (as Mg)	15mg/L	ICPAES
*Nitrate (as N)	11.5mg/L	Dr. Lange
Ammonia - N	4.55mg/L	SOP 2.103
pH	7.26	SOP 2.125

ND - When shown indicates not detected.

Signed : Ciaran Geoghegan
Ciaran Geoghegan Ph.D.

Date : 12-July-1996

ILAB

Analysis Report

13 AUG 1996

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Pharmaceutical • Chemical • Food • Environmental

Ms Margaret Stokes
Minorco Lisheen
Lisheen Site Office
Kilclonagh
Thurles
Co Tipperary

Sample Type : Water
DAY 1 - Pumping

Date Received: 07/08/96
Date Analysed: 07/08/96

TESTS REQUIRED	METHOD
Coliforms	SOP 1.151.05
*Faecal Coliforms	SOP 1.159.01
Faecal Streptococci	SOP 1.152.04

LAB NO	Batch No	Coliforms Cfu/100ml	Faecal Coliforms Cfu/100ml	Faecal Streptococci Cfu/100ml
9621113	-	<1	<1	<1

Signed Mary Dwyer

Date 9 August 1996

Ms Mary Dwyer
Laboratory Manager (Microbiology)

Analysis Report

18 JUL 1996

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Ms Margaret Stokes.
Minorco Lisheen Ltd.
Lisheen Site Office,
Kilclonagh,
Thurles,
Co Tipperary.

Sample Type : Water

Received Date : 04/Jul/96
Analysis End Date : 16/Jul/96

Lab Number :	963665
Batch Number :	Bottle 2 Day 3 Pumping

Test Parameter	Result	Test Method
pH	7.32	SOP 2.125
*Conductivity	759uS/cm	SOP 2.115
*Chloride	28mg/L	Potentiometric titration
*Sulphate	19mg/L	SOP 2.105
Ammonia - N	0.04mg/L	SOP 2.103
*Nitrate (as N)	10.8mg/L	Dr. Lange
*Nitrite (as N)	ND<0.025mg/L	SOP 2.106
*Calcium (as Ca)	126mg/L	ICPAES
*Magnesium (as Mg)	16mg/L	ICPAES

ND - When shown indicates not detected.

Signed : Declan Halpin

Declan Halpin Technical Manager (Chemistry

Date : 16-July-1996

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*Zinc (as Zn)	134ug/L	ICPAES
*Lead (as Pb)	ND <10ug/L	ICPAES
*Potassium (as K)	1.80mg/L	ICPAES
*Sodium (as Na)	9.90mg/L	ICPAES
*Aluminium (as Al)	ND <10ug/L	ICPAES
*Copper (as Cu)	114ug/L	ICPAES
*Fluoride	0.24mg/L	Ion Selective Electrode
*Suspended solids	1mg/L	SOP 2.111
*Arsenic (as As)	ND<5ug/L	ICPAES
*Cadmium (as Cd)	ND <5ug/L	ICPAES
*Chromium (as Cr)	ND <10ug/L	ICPAES
*Nickel (as Ni)	80ug/L	ICPAES
*Detergents (as MBAS)	0.11mg/L	SOP 2.110
Phosphorous (soluble reactive as P)	ND<0.025mg/L	SOP 2.104
*Barium (as Ba)	0.23mg/Kg	ICPAES
*Silver (as Ag)	0.15mg/L	ICPAES
*Mercury (as Hg)	ND<0.1ug/L	Cold vapour AA
*Kjeldahl Nitrogen	11mg/L	SOP 2.136

ND - When shown indicates not detected.

Signed : Declan Halpin Date : 16-July-1996

Declan Halpin Technical Manager (Chemistry

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*Hydrogen Sulphide	ND<0.20mg/L	A.P.H.A.

ND - When shown indicates not detected.

Signed : Declan Halpin
Declan Halpin Technical Manager (Chemistry

Date : 16-July-1996

Test Parameter	Result	Method
*Hydrocarbons	Not detected <0.1mg/L	Capillary Gas Chromatography
*Phenol	Not detected <10µg/L	SOP 2.109
***Polyaromatic Hydrocarbons**		Capillary Gas Chromatography
Fluoranthene	Not detected <10ng/L	
Benzo (b) fluoranthene	Not detected <20ng/L	
Benzo (k) fluoranthene	Not detected <20ng/L	
Benzo (a) pyrene	Not detected <20ng/L	
Indeno (1,2,3,CD) pyrene	Not detected <20ng/L	
Benzo (ghi) perylene	Not detected <20ng/L	
***Polychlorinated Biphenyls**		Capillary Gas Chromatography
2,4,4'-Trichlorobiphenyl	Not detected <10ng/L	
2,2',5,5'-Tetrachlorobiphenyl	Not detected <10ng/L	
2,2',4,5,5'-Pentachlorobiphenyl	Not detected <10ng/L	
2,3,4,5,5'-Pentachlorobiphenyl	Not detected <10ng/L	
2,2'3'4,4'5-Hexachlorobiphenyl	Not detected <10ng/L	
2,2',4,4'5,5'-Hexachlorobiphenyl	Not detected <10ng/L	
2,2',3,4,4'5,5'-Heptachlorobiphenyl	Not detected <10ng/L	
***Organochlorine Pesticide Residues**		Capillary Gas Chromatography
Benzene Hexachloride & Isomers	Not detected <0.05µg/L	
Heptachlor & Heptachlor Epoxide	Not detected <0.05µg/L	
Aldrin & Dieldrin	Not detected <0.05µg/L	
DDT and Isomers	Not detected <0.10µg/L	
***Organophosphorous Pesticide Residues**		
Disulfoton	Not detected <0.05µg/L	
Ethion	Not detected <0.05µg/L	
Malathion	Not detected <0.05µg/L	
Methyl Parathion	Not detected <0.05µg/L	
Phorate	Not detected <0.05µg/L	

Signed Declan Halpin

Mr Declan Halpin
Technical Manager (Chemistry)

Date 2 August 1996

Analysis Report

14 AUG 1996

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Pharmaceutical • Chemical • Food • Environmental

Ms Margaret Stokes
Minorco Lisheen
Lisheen Site Office
Kilclonagh
Thurles
Co Tipperary

Sample Type : Water

Date Received: 09/08/96
Date Analysed: 09/08/96

LAB NO	9621415	
BATCH NO	Sample 2 9/8/96 Day 3 Pumping	
Test Required	**Result**	**Method**
Coliforms Cfu/100ml	<1	SOP 1.151.05
***Faecal Coliforms Cfu/100ml**	<1	SOP 1.159.01
Faecal Streptococci Cfu/100ml	<1	SOP 1.152.04

Comments: Faxed handwritten 12/8/96

Signed Mary Dwyer Date 13 August 1996

Ms Mary Dwyer
Laboratory Manager (Microbiology)

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APPENDIX 2

Boreholes logs of test wells and production wells from

Patrick Briody and Sons - Aquadril Services, 1996

Test Well (1)

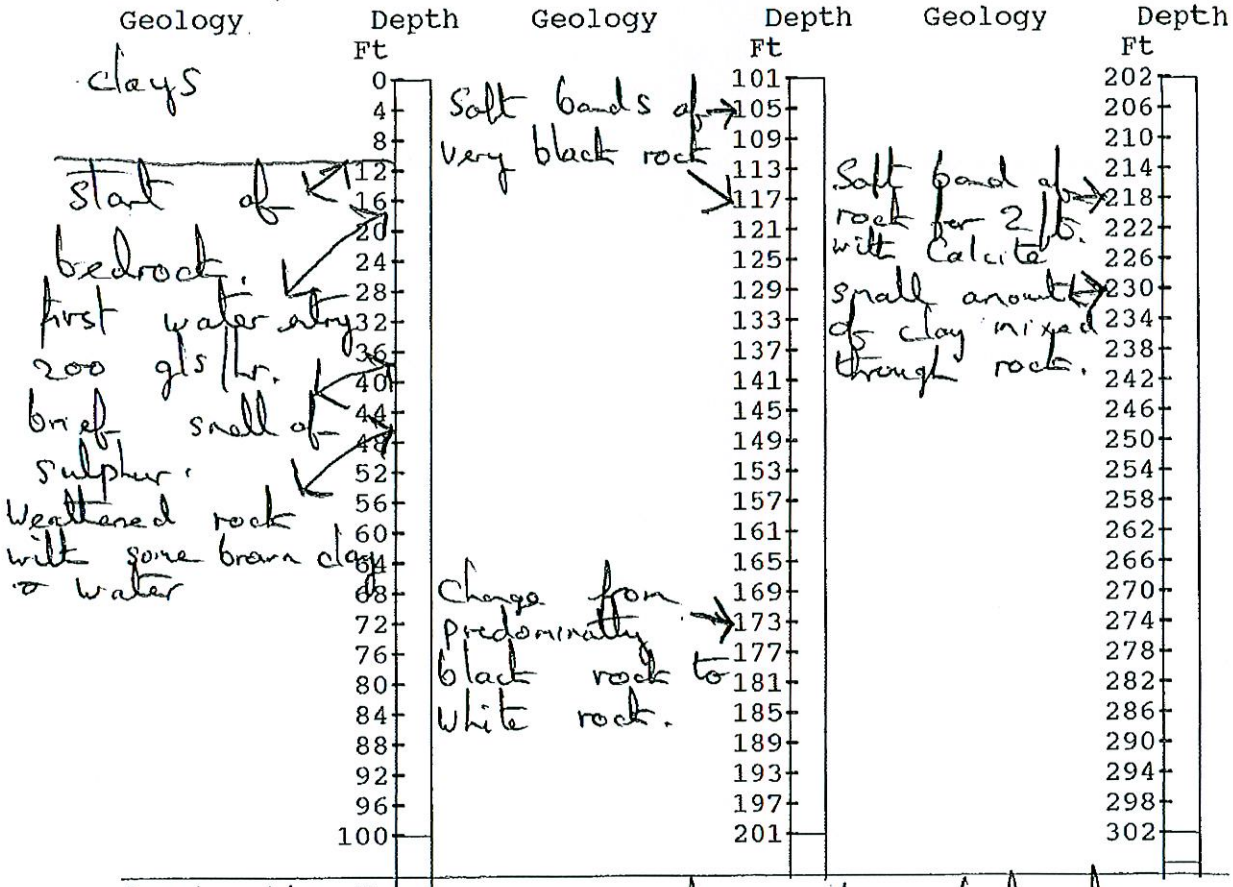
Willie Stapletons field beside road

Minorco Lisheen,Ltd.
Daily Drilling Log

Patrick Briody & Sons
Aquadril Services
Rathangan
Co. Kildare
Authorised By Aidan Briody

Date 6-6-'96

> = Water Entry,<...> = Start Drilling Depth,>...< = End Depth



Construction Notes

Opened up @ 8" dia into bedrock.
at 14 feet
Installed 15 ft of 6" Casing
Drilled 6" dia from 15 ft to 480 ft.

V-Notch Measure("20ft Intervals) Penetration Test(20ft Intvls)

20ft ____"	160ft ____"	20ft ____"	160ft 15m"
40ft ____"	180ft ____"	40ft 15m"	180ft 16m"
60ft ____"	200ft ____"	60ft 15m"	200ft 15m"
80ft ____"	220ft ____"	80ft 15m"	220ft 15m"
100ft ____"	240ft ____"	100ft 15m"	240ft 14m"
120ft ____"	260ft ____"	120ft 12m"	260ft 17m"
140ft ____"	280ft ____"	140ft 17m"	280ft 17m"
	300ft ____"		300ft 20m"

This was a low yeilding borehole - approx 3000 gals/hour. Abandoned MDunne 17/6/96

Test well
Willie Stapletons field, beside road

Minorco Lisheen, Ltd.
Daily Drilling Log

Patrick Briody & Sons
Aquadril Services
Rathangan
Co. Kildare
Authorised By Aidan Briody

Date 7-6-96

> = Water Entry, <...> = Start Drilling Depth, >...< = End Depth

Geology	Depth Ft	Geology	Depth Ft	Geology	Depth Ft
	303		407		511
	307		411		515
	311		415		519
	315		419		523
	319		423		527
	323		427		531
	327		431		535
	331		435		539
	335		439		543
	339		443		547
	343		447		551
	347		451		555
	351		455		559
	355		459		563
	359		463		567
	363		467		571
	367		471		575
	371		475		579
	375	End of Hole. →	479		583
	379		483		587
	383		487		591
	387		491		595
	391		495		599
	395		499		604
	399		503		608
	403		507		612

Construction Notes

V-Notch Measure("20ft Intervals)

320ft ____"	460ft ____"	320ft 20m"	460ft 25m"
340ft ____"	480ft ____"	340ft 20m"	480ft 25m"
360ft ____"	500ft ____"	360ft 20m"	500ft ____"
380ft ____"	520ft ____"	380ft 25m"	520ft ____"
400ft ____"	540ft ____"	400ft 25m"	540ft ____"
420ft ____"	560ft ____"	420ft 25m"	560ft ____"
440ft ____"	580ft ____"	440ft 25m"	580ft ____"
	600ft ____"		600ft ____"

Penetration Test(20ft Intvls)

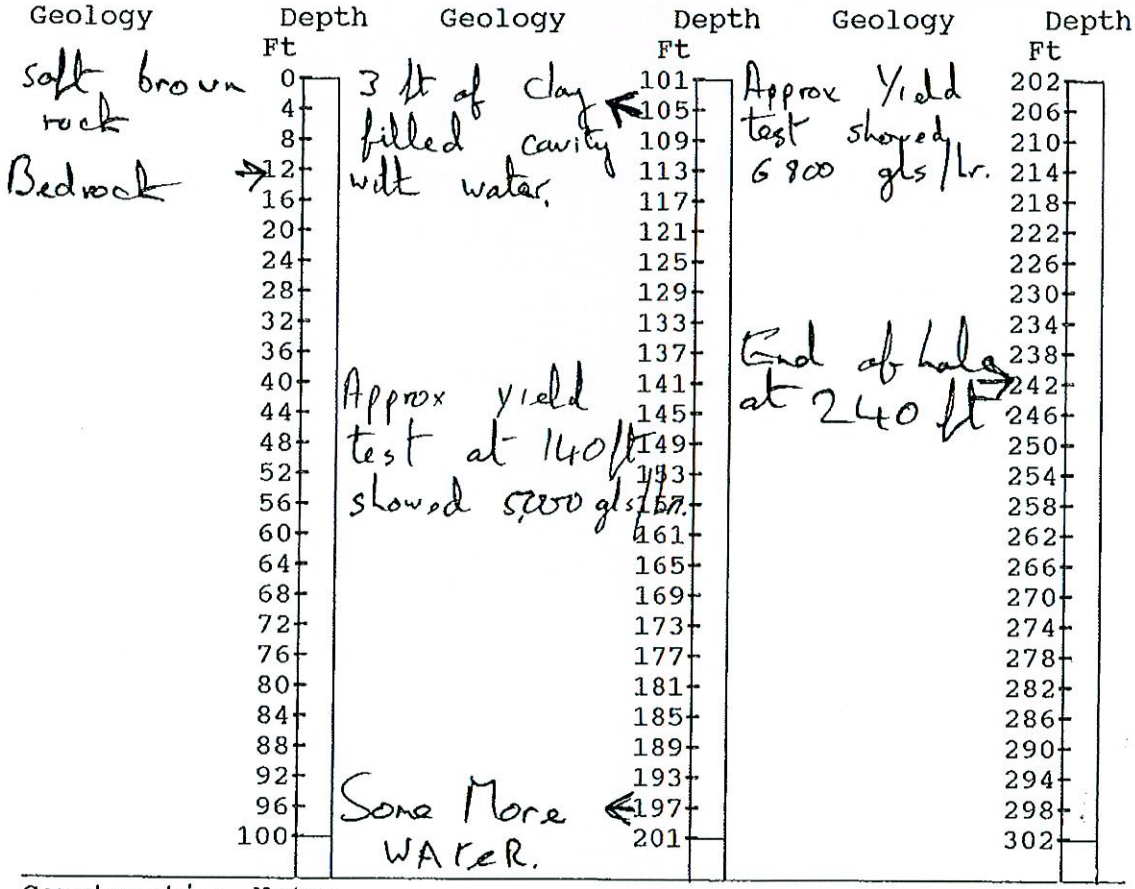
Test Well (2)
Middle of Willie Stapletons field.

Minorco Lisheen,Ltd.
Daily Drilling Log

Patrick Briody & Sons
Aquadril Services
Rathangan
Co. Kildare
Authorised By Aidan Briody

Date 10-6-96.

> = Water Entry,<...> = Start Drilling Depth,>...< = End Depth



Construction Notes

Opened up at 8" dia into bedrock at 14' feet
Installed 15' of 6" liner.
Drilled 6" dia from 15 feet to 240 ft.

V-Notch Measure("20ft Intervals)

20ft ____"	160ft ____"	20ft ____"	160ft 17m"
40ft 15m"	180ft ____"	40ft 15m"	180ft 17m"
60ft 15m"	200ft ____"	60ft 15m"	200ft 20m"
80ft 15m"	220ft ____"	80ft 15m"	220ft 20m"
100ft 15m"	240ft ____"	100ft 15m"	240ft 20m"
120ft ____"	260ft ____"	120ft 20m"	260ft ____"
140ft ____"	280ft ____"	140ft 15m"	280ft ____"
	300ft ____"		300ft ____"

Penetration Test(20ft Intvls)

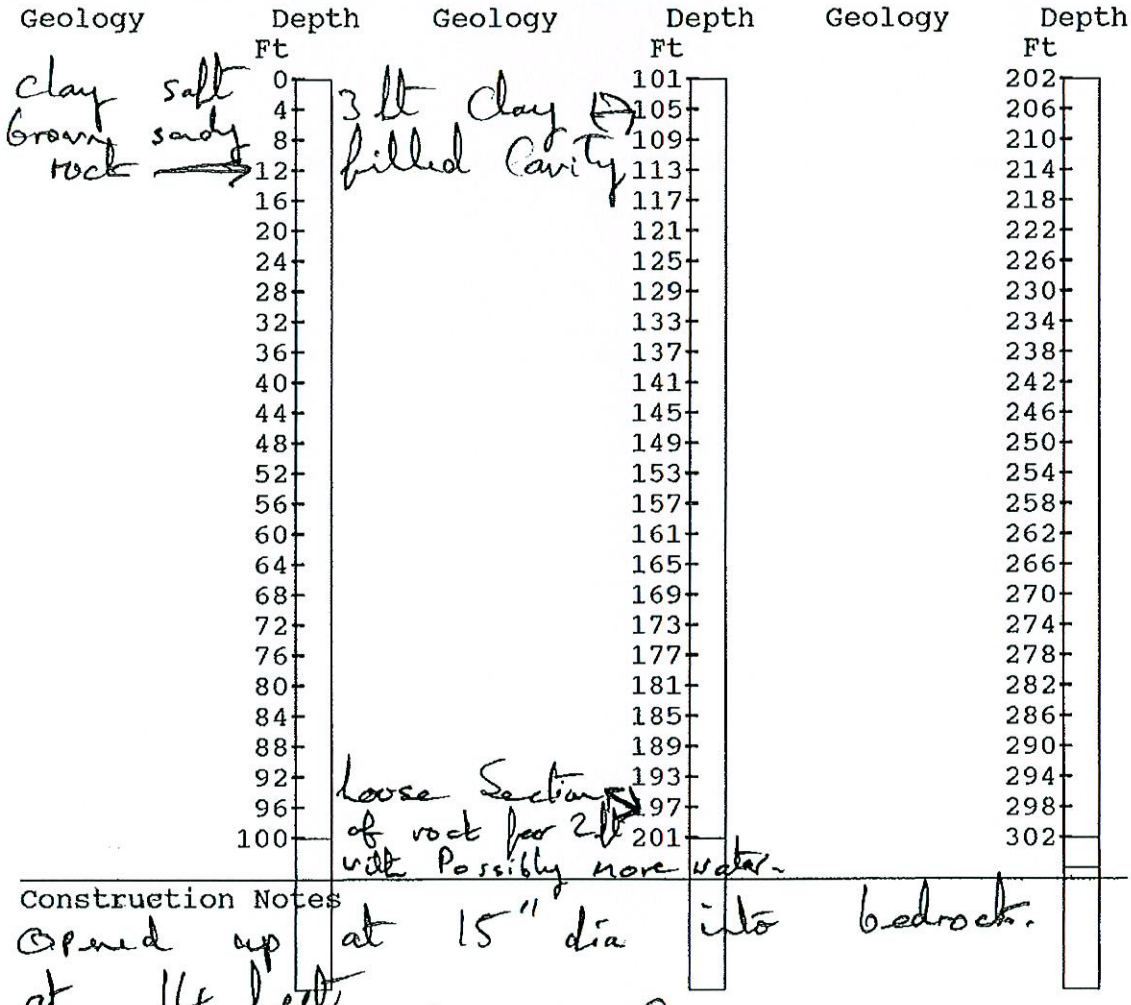
Production Well on test well 2
Willie Stapletons field (middle of).

Minorco Lisheen,Ltd.
Daily Drilling Log

Date 11-6-96

Patrick Briody & Sons
Aquadril Services
Rathangan
Co. Kildare
Authorised By Aidan Briody

> = Water Entry,<...> = Start Drilling Depth,>...< = End Depth



Construction Notes

Opened up at 15" dia into bedrock.
at 14 ft
Installed 15' of 12" Casing
Drilled 12" dia from 15" to 235 ft.

V-Notch Measure("20ft Intervals)

20ft ____"	160ft ____"	20ft ____"	160ft 35m"
40ft ____"	180ft ____"	40ft 20"	180ft 35m"
60ft ____"	200ft ____"	60ft 20"	200ft 40m"
80ft ____"	220ft ____"	80ft 25"	220ft 40m"
100ft ____"	240ft ____"	100ft 20"	240ft 43m"
120ft ____"	260ft ____"	120ft 25"	260ft 40m"
140ft ____"	280ft ____"	140ft 30"	280ft 35m"
1½ hr. Well	300ft ____"		300ft 40m"

development

Installed 235 ft of 8"(ID) P.V.C.
Drilled 8" dia from 235 ft to 340 ft.
2 hrs Well Development. Lockable lid.

Production Well
Willie Stapletons field (Middle of).

Minorco Lisheen,Ltd.
Daily Drilling Log

Patrick Briody & Sons
Aquadril Services
Rathangan
Co. Kildare
Authorised By Aidan Briody

Date 17-6-96.

> = Water Entry,<...> = Start Drilling Depth,>...< = End Depth

Geology	Depth Ft	Geology	Depth Ft	Geology	Depth Ft
	303		407		511
	307		411		515
	311		415		519
Possibly more water. (higher air reading). →	315		419		523
	319		423		527
	323		427		531
	327		431		535
	331		435		539
	335		439		543
	339		443		547
End of Hole. ←	343		447		551
	347		451		555
	351		455		559
	355		459		563
	359		463		567
	363		467		571
	367		471		575
	371		475		579
	375		479		583
	379		483		587
	383		487		591
	387		491		595
	391		495		599
	395		499		604
	399		503		608
	403		507		612

Construction Notes

V-Notch Measure("20ft Intervals)				Penetration Test(20ft Intvls)			
320ft	____"	460ft	____"	320ft	40m"	460ft	____"
340ft	____"	480ft	____"	340ft	40m"	480ft	____"
360ft	____"	500ft	____"	360ft	____"	500ft	____"
380ft	____"	520ft	____"	380ft	____"	520ft	____"
400ft	____"	540ft	____"	400ft	____"	540ft	____"
420ft	____"	560ft	____"	420ft	____"	560ft	____"
440ft	____"	580ft	____"	440ft	____"	580ft	____"
		600ft	____"			600ft	____"

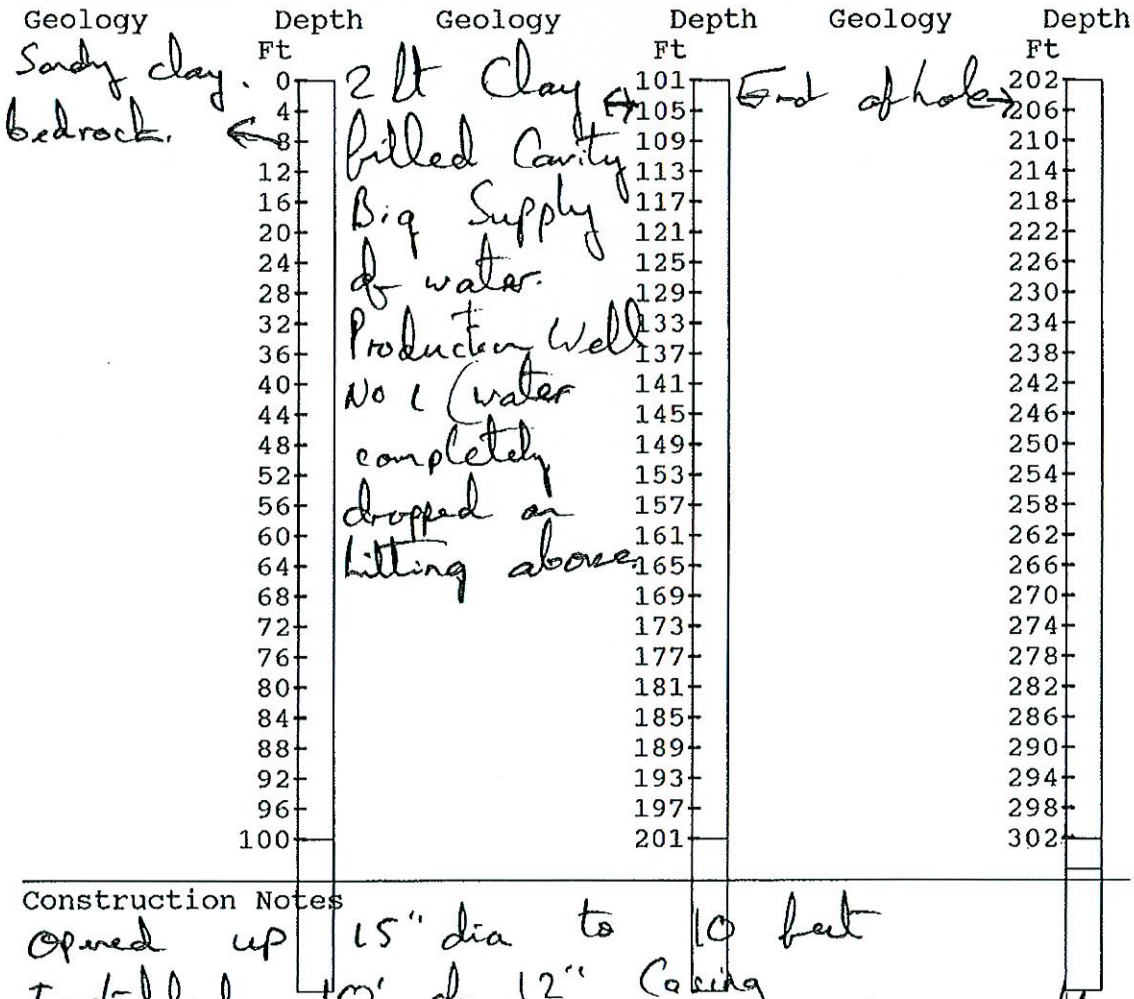
Production Well NO 2
(Middle of Willie Staplestons field)

Minorco Lisheen,Ltd.
Daily Drilling Log

Patrick Briody & Sons
Aquadril Services
Rathangan
Co. Kildare
Authorised By Aidan Briody

Date 18 June '96

> = Water Entry,<...> = Start Drilling Depth,>...< = End Depth



Construction Notes

Opened up 15" dia to 10 feet
Installed 10' of 12" Casing
Drilled 12" dia from 10 ft to 205 ft.
1½ hrs Well development.

V-Notch Measure("20ft Intervals)

20ft ____"	160ft ____"	160ft 45m"	
40ft ____"	180ft ____"	180ft 50m"	
60ft ____"	200ft ____"	200ft 50m"	
80ft ____"	220ft ____"	220ft ____"	
100ft ____"	240ft ____"	240ft ____"	
120ft ____"	260ft ____"	260ft ____"	
140ft ____"	280ft ____"	280ft ____"	
	300ft ____"	300ft ____"	

Penetration Test(20ft Intvls)

20ft ____"	160ft 45m"		
40ft 20m"	180ft 50m"		
60ft 25m"	200ft 50m"		
80ft 35m"	220ft ____"		
100ft 40m"	240ft ____"		
120ft 40m"	260ft ____"		
140ft 45m"	280ft ____"		
	300ft ____"		

Installed 200 ft of 8" (ID) P.V.C.
2 hrs Well dev. / Grout for both Wells
Lockable lid. @ 60 bags.